



Academic Promoter

Paul Bailleul

Industrial Promoter

Luc Lebon

FOREWORD

This paper describes the journey, leading up to the design of a new generation concept for the Smartbike service run by Clear Channel Outdoor. Herein is described the design progress from first inspiration to final product, the issues encountered during the course of the project, and the decisions that resulted from them. The end result is a concept proposal, divided over three project touch points: a bicycle, a station and a supporting digital application. This document should be read as a source of inspiration for research and development in the sector of bike sharing, wherein numerous solutions are discussed that all could provoke innovation for each given opportunity. The product that is presented to you is but the tip of the iceberg, a premium selection from the masses: the possibilities for feasible innovation are endless.

I cordially invite you to the interesting and complex world of bike sharing, and hope you will become fascinated by it, whilst you are reading this document, the way I was fascinated whilst writing it.

I want to pay special thanks to my mentor Paul Bailleuil, who has more than lived up to the title during the course of this academic year. Furthermore I would like to thank Chris Baelus and Jan Van Goey for eventually guiding me towards bike sharing as a thesis subject, and support throughout the year. I would like to thank the other tutors who have helped me with their counsil during the course of the year.

I would like to thank Luc Lebon, my industrial promotor, for guidance and motivation, as well as Dimitri Rondeaux and Semun Alagas for their cooperation

I would like to thank my parents, for standing by me in times both jolly and sad. I would like to thank my girlfriend for not giving up on me during times of stress and short temper, of which there were a few. I would also like to thank all of my friends, which special mention of Jeroen Claus, for being a mutual source of inspiration and a great frustration outlet.

And I thank you, who reads this document, for taking the time to delve into a project which I've worked on for the better part of a year, and I hope that you will be inspired by its content. Enjoy the ride.

TABLE OF CONTENTS

New Product Planning

Bike-Sharing: A Public Transport Pandemic	
What Is Bike Sharing?	
Mobility Benefits	
Main users	
Relevance Of The Project	
Personal Motivation	
Partnerships	
The Involvement Of Clear Channel Belgium	
The Involvement Of BlueCorner	
The Project	
New Product Planning	
Integrated Product Design	
Design Approach	
Research Strategy	29
(T O	01 : 0 : 01 1
it Is The Current State Of The Art For Bicycl	
Generations Of Public Bike Sharing	
First Generation	
Second Generation	
Third Generation	
Beyond The Third Generation	
The future of bicycle sharing, the aim of the project	
Conclusion	
Service Mapping And Case Studies	
Cyclocity	
Cyclocity Bicycles	
The Vélib Programme (PARIS)	
Cykel DK	
Cykel DK Bicycles Cykel DK In The Media	
Saturation	
Smoove	
Smoove Bicycles	
Smoove Systems	
SmartBike	
Smartbike Bicycles	
Smartbike Service	
The Bicing Programme (BARCELONA)	
Conclusion	
General Findings	
Proper User Identification	
Scale	
Scale	44
Implantation	
ImplantationBicycle Availability	44
Implantation	44 44

New Technology In A Familiar System	
Digital Complements	46
Mounted digital components	
Full Smartphone Compatibility	
Bicycle Availability	
Provision EV's	
Fast-Install Stations	
Power Efficiency	
Sleep Mode Stations	
The Electric Bicycle	
Signature Technology	
Two Models	
Charging Models	
Inductive Charging	
Conclusion	54
Reducing Costs For Infrastructure	54
The Potential Of The Electric Bicycle	54
Embedment In A Digital Service	
A Durable Product	54
Which Society-Based Opportunities Could Make Experience? Real-Time Digital Tracking	56
User Comfort	
Locating Bicycles	
Service Infrastructure Improvements	
Placing reservations	56
General Infrastructure Improvements: Desire Lines	
Bicycle Helmets	58
Previous Experience	
Mikael Colville-Andersen On The Subject Of Bicycle Helmets	
Bicycle Helmets In A Culture Of Fear	
How Fast Is Too Fast?	
Cargo Space	
Opportunity For Additional Space	
Cargo Bikes Tricycles	
Covered Bicycle	
The Bane Of Bicycles	
Great Possibilities	
Numerous Problems	
Push And Pull Stations	
Conclusion	
Reliability	64
Safety of the product	
New Bicycle Types	64
Field Research: The Third Generation Clear Char	
Setup	
Using the service	66
Mapping Out Bicycle Provision	68
The Regulators	
Station Balancing	
Dispatch	
Infographic: The Status Quo	
Velo-Antwerpen: Estimated Shifts In User Demographics	
Userbase Stakeholders: Part-Fictional Persona's	
The Busy Bee	
The Unlucky Commuter	
Design Vision: The Fourth Generation	
Digital Platform	//

The C	Concept	
	Product Features	. 7:
	A Better Bicycle	
	A Dynamic Station	
	Digital System Enhancements	
	Product Architecture	
	The Station Module	
	The Bicycle	
	Added Value	
	New Bicycles	
	Dynamic stations	
	Digital platform	
	Overall benefit	
	Items To Be Developed	
	Project Verification	
	Product relevance	
	Technical Feasibility	
	Financial viability	
	Significant Innovative Character	
	Opportunity for growth	
Desig	n Drivers: Introducing A New Generation	
_ 00.5	A Premium Product	8
	A Beautiful Product	
	Healthy Public Transit	
	International Compatibility	
	A Positive Future Image	
	Faster And Further	
	Power Efficient	
	A Better City	
	An Easy Transition	
	Easy Charging Experience	
	A Trusted Service	
	A Cycling Lifestyle	. 8
	An Adaptive Service	
	Reliable At Any Time Of Day	8
	Digital Enhancement	8
	Regulation efficiency	. 8
Produ	ıct Constraints	
	System (Global)	. 8
	The Bicycle	
	Dynamic Stations	
	Digital Service	
	Digital Del Vice	
Ectim	ated Financials	
∟5tiii		0
	Estimation Approach	
	Data Acquisition	
	Year-Pass Estimated Cost	
	Clear Channel Operational Expenses	9:

Conclusion: New Product Planning

System Design

Defi	ining the next generation	
	Three Touch Points	101
	A New Bicycle	
	A Better Station	101
	Digital Enhancement	
	Defining A Network: The Main Actors	102
۸ D	lynomic Station	
AD	ynamic Station	404
	Modular Station	
	Complicated Puzzle	
	Wagon ModelAGV Transport	
	The Secret Design Drivers	
	Compact Storage	
	Modular Structure	
	Efficient Transport	
	Economic Solution	
	Vehicle Compatibility	
	Little To No Installation Cost	
	Manoeuvrable	
	Mechanical Simplicity	
	Intermodal Modules	
	Designing A Universal Station	
	Smartphone Access	
	Module Power Supply	108
	Module Connectors	110
	Battery Life And Bicycle Allotment	112
	The Bicycle Couplers	
	Considering inductive versus conductive charging	114
	Conductive Method: Jack Pin	
	Conductive Method: Powered Locker Axis	115
An I	E-bike For Public Purposes Decomposing The Electric Bicycle	
	Bicycle Structural Components	
	The Motor Assembly	
	Choice of Battery Model	
	Motor Option: Rear Wheel Hub	
	The Smart Wheel	
	Gruber Assist Kit	
	Coaxial Motor Unit	
	Considering The Smartbike Architecture	
	Bike Rack And Binder	
	Bike Seat	
	Smart Device Mount	
	Mechanical Fixture	
	Sticky Pad Technology	
	Decisions	125
Mol	bile Functionality	
	Lifestyle Branch	128
	Positioning	128
	A Community	
	Tourism	
	Timekeeping	
	Interlinked Public Transit	
	Track Monitor	
	Bicycle Branch	
	Reservations	129

	On The Verge Of Product Design	135
•	A Summary	134
Cor	nclusion: System design	
	Account branch	133
	Options Branch	
	Active Ride: This Ride Branch	
	The Road Map Screen	
	Regarding Time-Credit: To Gamify Bike Sharing	
	Defect Report	130
	Flexible Reservations	130
	Reserved Bicycles	130
	Second Model: Set Timespan Reservation	129
	First Model: Fixed Timespan Reservations	
	Flexibility	129

Product Design

Bui	Ilding The Station	
	The Station Structure	138
	Station Kiosk	138
	The Fixed Module	
	The Dynamic Modules	140
	Roofless Stations	
	Station Zoning and Clearances	
	Sheetmetal Covers	
	Station Electronics	
	Station Signalling	
	Simplified Signalling	
	Materializing the Lockers	
	Insulation	
	Replacing Gear Transmission	
Des	signing the Bicycle	
	Design Direction	150
	Designing The Bicycle Frame	152
	Pot Lid Model	
	A reimagined model	
	Components	153
	Structural Analysis: Bicycle Frame	155
	Factor of Safety Analysis	
	Hiding the Cables	158
	Added Value	158
	Front Fork And Rear Wheel	158
	The "Dashboard"	159
	Luggage Rack	160
	The Smartphone Socket	162
	Ad Revenue Generation	164
\/:		
VIS	ualizing A Digital Platform	400
	General style and approach	
	Interaction Ergonomics: Unified Interface	
	Menu Bar	
	Button Design	
	The Main Menu Tabs	
	Map Screen	
	Reservations	
	Ride Statistics	
	Report Defects	
	User Profile	
	Community Panel	
_		

Conclusion: Product design

Conclusion: Overall Project

Final Words

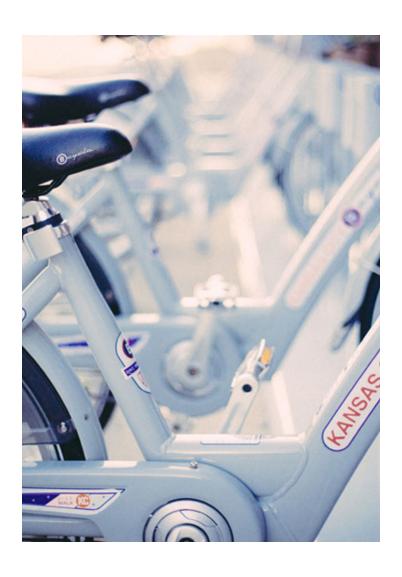
Appendix A: Orthographic Views and Overall Dimensions

Appendix B: Observed Programmes

List Of References

List Of Figures

Figure 1 : Annual increase of total operational bicycle sharing services worldwide (Metrobike, 2012)	27
Figure 2 : Spectrum of Urban Trips (Alta Planning + Design, 2012)	28
Figure 3 : The four generations of bicycle sharing (Alta Planning + Design, 2012)	35
Figure 4 : Direct charging model	52 52
Figure 5 : Indirect charging model Figure 6 : Inductive charging process explained (Mechanical Engineering Online, 2011)	52 54
Figure 7 : The concept of desire lines	59 59
Figure 8 : Pedestrian injuries at impact speeds (Copenhagenize, 2013)	61
Figure 9 : A possible model of pedal assistance relative to user input at different speeds (Electric Bicycle Guide, 2012)	61
Figure 10 : The ELF-Cycle: cheapest, lightest and most popular covered bicycle on the market to date (Phys. Org, 2013)	63
Figure 11 : Envisioned positioning/disposal while riding the bicycles.	65
Figure 12 : User interactions for a singular use of the Velo-programme	69
Figure 13 : Regulator interactions during the preparation process, and a singular iteration of bicycle regulation	71
Figure 14: Estimated shifts in the elderly population figures (Department of Population Antwerp, 2007)	74
Figure 15 : Velo-Antwerpen user age demographics (Rondeaux, 2013)	74
Figure 16 : Sketched quickdesign of the bicycles' form factor, visibly reflecting the Clear Channel line of products Figure 17 : Envisioned product architecture of single station module	81 82
Figure 18 : Envisioned product architecture with significant new features of the nextgen bicycle	83
Figure 19 : Possible difference in the service's yearly operational expenses by optimizing regulation	96
Figure 20 : Different actors in the bike sharing system, and their relevance in different interactions.	104
Figure 21 : Modular Station Principle	107
Figure 22 : Battery powered modules versus central power supply	110
Figure 23 : The sheetmetal coverplate principle	112
Figure 24 : Schematic representation of the coverplate workings	113
Figure 25 : Battery Requirements	114
Figure 26 : Bicycle allotment according to battery life	115
Figure 27: Quickdesigns regarding power transmission from the locker on to the bicycle	116
Figure 28 : Schematic representation of the locker assembly	117
Figure 29 : 2013 C onventional ebike study Figure 30 : Schematic representation of Smartbike inner architecture	118 119
Figure 30 : Scriematic representation of Smartbike limer architecture Figure 31 : Pedal axis torque sensor module (Machinedesign, 2013)	120
Figure 32 : Flykly Smart Wheel (FlyKly, 2013)	121
Figure 33 : Gruber Assist Kit (Gruber Assist, 2013)	122
Figure 34 : Coaxial Motor Unit (Eprodigy Bikes, 2014)	123
Figure 35 : Old quickdesign where luggage was stored in between the rider's knees	124
Figure 36 : Schematic representation of the saddle adjustment	125
Figure 37 : Two possible conventional mounting principles for smartphones	126
Figure 38 : Schematic representation of a smartphone cover and the holder	127
Figure 39 : Brainmapping of digital platform functions	129
Figure 40 : Flexible Reservation Mechanics	132
Figure 41: Schematic representation of the Digital Platform interface	134
Figure 42 : Integrating tourism applications may encourage touristic destinations for system implementation Figure 43 : The dynamic module (right) and the fixed module (left)	135 142
Figure 44 : Dynamic Station walking clearances	143
Figure 45 : Schematic depicting the fixed module power layout	144
Figure 46: See-through detail of the station sheetmetal cover, depicting the new locking system	145
Figure 47 : Schematic representation of the connector lock	145
Figure 48 : Three visual displays on the stations of different signalling solutions	147
Figure 49 : The general layout for the materialised locker	148
Figure 50 : Guiding moodboard for the general design language	153
Figure 51: Key sketch for the bicycle frame	154
Figure 52: Production of different frame pieces	155
Figure 53: Loads and fixtures placed on the frame model	158
Figure 54: The two factor of safety plots for a wall thickness of 1mm (left) and 3mm (right)	159 160
Figure 55 : Cutaway view of the bicycle's fork, with blue wiring tucked into subtle grooves Figure 56 : Dashboard wiring	161
Figure 57 : Schematic representation of the head tube wiring and handlebar clamp	161
Figure 58 : Technical sketches of charger cable protection measures within the luggage rack	162
Figure 59 : Cutaway view of the luggage rack	163
Figure 60 : Luggage rack strength diagram	163
Figure 61 : Smartphone holder, an exploded view	164
Figure 62: The smart device holder and USB-port	165
Figure 63 : 4 models for advertising placement	166
Figure 64: Renders of the final bicycle model	167
Figure 65: Two graphic styles considered for the digital application.	170
Figure 66 : Main menu button semantics Figure 67 : Button type semantics	172 172
Figure 67 : Button type sernantics Figure 68 : Map Screen and Reservations Submenu	172
Figure 69 : This Ride Tab and Defect Report Submenu	173
Figure 70 : User Profile Tab and Community Panel Submenu	175
\cdot	



new products planning

The first part of this thesis document reports on the exploration and research performed within the domain of bike sharing systems. Public bike sharing is a very contemporary subject, with a multitude of services now saturating the greater cities of the modern world. The successes of bike-sharing, and its consequential growth are still quite young. Most of the programmes currently in operation, sprout from within the past decade, and many opportunities for innovation lie ahead. The focus of this research is to explore the possibilities that may lift bicycle sharing into a new generation.

public bike sharing and the future of urban mobility

1. The Concept Of Bike Sharing

In the spring of 2008, there were as much as 213 bike sharing programs in operation worldwide. Three years later, in 2011, this number had increased to 375 systems. As of April 2013, the number of sharing services worldwide had grown to 535: a rather exponential increase in popularity. Peter Midgley (2011), as cited in Larsen (2013) states that "bike sharing has experienced the fastest growth of any mode of transport in the history of the planet."

Bike-Sharing: A Public Transport Pandemic

Mobility infrastructure of present- day cities is centred mostly on automobile functionality. This can be defined as the "car-centric city infrastructure". For the last 50 years the mobility channels of these cities have been constructed for the comfort of motorists, while other means of transport were often overlooked. Today, in a modern city -planned to more effectively fight congestion other means of transport must be prioritized: public transit, a better pedestrian infrastructure, and the use of bicycles.

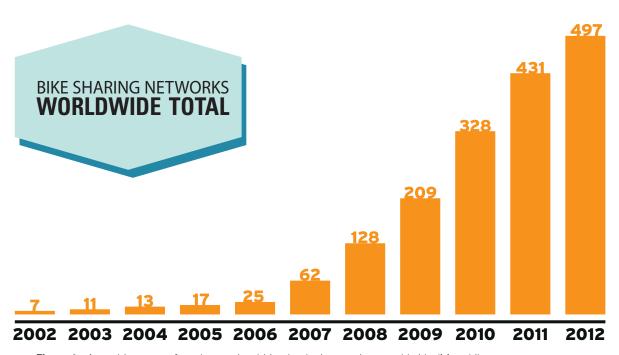


Figure 1 : Annual increase of total operational bicycle sharing services worldwide (Metrobike, 2012)

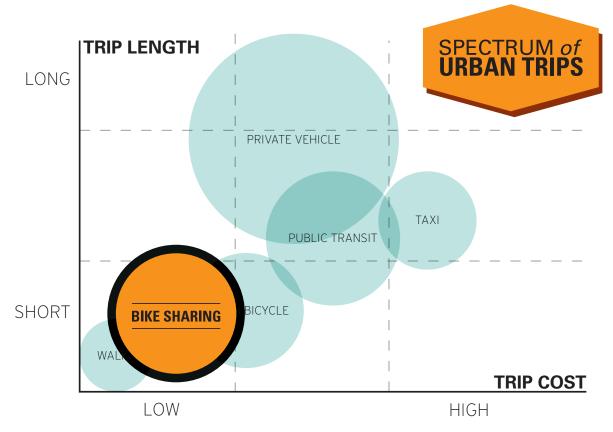


Figure 2: Spectrum of Urban Trips (Alta Planning + Design, 2012)

What Is Bike Sharing?

Bike sharing is a low-cost form of public transport. A typical sharing system consists of stationary hubs, positioned at numerous strategic locations around a particular city. At these stations a number of bicycles are made available for users to bridge short distances within the city. One can borrow the bikes and ride them from station to station, much like a public bus-scheme, but at lower usage fees and with added flexibility. The system is meant, neither to replace the private bicycle, nor to replace other variants of public transit. It is typically aimed at commuters who need a transport medium to cross 'that last mile' from i.e. the train station to the workplace, or tourists who need a cheap means to get around in the city centre.

Mobility Benefits

Public bicycle sharing is a great improvement to urban mobility infrastructure, providing a whole new mode of transport for short-distance travel. It's faster and more long-ranged than pedestrian travel, and at the same time cheaper and more flexible than travel by bus or streetcar. "Bike sharing fills an existing gap between trips too long to walk, but not long enough to justify waiting for a bus or the cost of driving or catching a taxi." (Alta Planning + Design, 2012) This is illustrated in Figure 2.

Main users

"Bike-share programs are used by a wide variety of people of all ages. Commuters, recreational or errand riders, and tourists are the three main user groups. Most bike-share users are not competitive cyclists." (Alta Planning+Design, 2012)

Relevance Of The Project

A thesis project, seeking to achieve innovation in the field of public bike sharing is relevant, as it applies to the primary aspects of Product Development.

- 1.) Technical depth: conceptualizing of technical systems and the creation of new product solutions in a project with a popular trending subject, using state-of-the-art technological possibilities.
- 2.) User centred design: usability aspects and the creation of an intuitive service with an ergonomic, emotionally compelling, attractive design that people want to be seen using.
- 3.) Economical factor: Solutions must be generated that will result in cost reduction on the level of operational costs, user fees and even overall economic benefit resulting from improved mobility.

Personal Motivation

This project suits my interests for transportation design. It is my ambition to make a career within the sector of transport, and therefore, to possibly attend a school of transportation design after finishing my studies in product development. From this project I hope to draw the necessary credibility to make such an education an option. My goals with the project, are to demonstrate my skills in ideation, verification and research, as well as presentation and, last but not least, the design and form factor of the products.

1.1. Partnerships

The Involvement Of Clear Channel Belgium

From the early stages, Clear Channel Belgium has been closely involved with the project. As the service showed great interest in any useful outcome, the project was directed for possible implementation in the Clear Channel Programme, specifically in Antwerp, Belgium. Later options for international use, however, are not out of the picture.

The Involvement Of BlueCorner

Early conversations with Clear Channel brought forth another party of interest: BlueCorner, owner of the largest EV charging network present in Belgium. In a consortium with other specialised companies, a similar project had been initiated for the implementation of e-bikes in the network of Velo-Antwerpen.

1.2. The Project

New Product Planning

The preliminary research, executed in the first segment of the project, comes from a broad angle. It incorporates an explorative research into the world of bike sharing: its opportunities, its critical flaws, its possibilities for future development. The aim of the analysis is to map out opportunities for a new generation of bike sharing, supervenient from both technological advancement, and user-driven demands. This research eventually results in a product candidate for a next generation bike-sharing service, featuring significant new technology relevant to the fourth generation of bike sharing, and beyond (See "2.1. Generations Of Public Bike Sharing" on page 22).

Integrated Product Design

The latter half of the project will be devoted to further development of selected systems that prove of pivotal significance to the project. These systems may be physical features on the bicycles themselves, elementary parts of the sharing infrastructure, or even digital applications in which the next generation service is embedded. A combination of the above is also possible.

1.3. Design Approach

The project is situated on multiple levels of design. A macro-level, a meso-level and a micro-level were defined. Macro-Level. The macro level comprises the whole system beyond the next generation network: Embedment in a digital system that improves the lifestyle of the user, the quality and responsiveness of the service, and the general mobility infrastructure of the city in general. Meso-Level. The meso-level consists of general concept generation for the system infrastructure. Overall design of the bicycles and station in regard to defined critical factors. General shape, structural integrity, and branding of the next generation product; Micro-Level. The micro-level holds the materialization process of certain systems that prove of critical importance to the project.

1.4. Research Strategy

The aim of this research is to explore opportunities that could lead to improvement of the current state of bicycle sharing. The research will be partly focused on the entirety of bike sharing, and is then instantiated in the form of a thorough research into the case of Clear Channel's Velo-Antwerpen. The main question that this research seeks to answer: "How can we achieve a true next generation bike sharing network?" The research strategy first envelops the world of bike sharing as a whole, and tries to define the essence of the bike sharing concept, as well as its critical factors of success: "What is the current state of the art for bicycle sharing systems globally?" These factors are then approached on a technological level, exploring technological advancements for improvement upon the current status quo: "New Technology In A Familiar System" Next, the bike sharing experience, and even the cycling experience in general is explored for opportunities that could invoke innovation: "Which Society-Based Opportunities Could Make For A Better Bike-Sharing Experience?" As a last part of the research, the current Clear Channel programme is put to the test. The programme was explored on a user level, and that of the service itself. The field research covers flaws, issues, and factors of relevance to the design project: What is the current status quo for Velo-Antwerpen? New Product Planning is then concluded with a first concept of how the next generation of bike sharing could operate: "How can we improve on this status quo? How can successful innovation be achieved?"



2. What Is The Current State Of The Art For Bicycle Sharing Systems Globally?

2.1. Generations Of Public Bike Sharing

The history of public bike-sharing progresses in waves, or generations, as mentioned by Midgley (2011) Bike sharing technology today has optimized its third generation technologies, and with up and coming innovations, many services find themselves on the brink of a new, fourth generation. A short summary of past generations will help put this transition into context.

First Generation

The first generation of public bike sharing dates back close to half a century ago. The first ever programme was initiated in July of 1968, in Amsterdam, Netherlands. It was named the White Bikes Programme ('Witte Fietsen') . The -roughly 50- White Bikes, spread around the city, were literally free to use. It was a primordial sharing service, with many flaws to be abused. Identification of users was simply out of scope at the time, as were any mechanisms for preventing theft and vandalism. The program faced an untimely termination with bikes thrown into the canals or kept for personal use. The many shortcomings of the White Bikes Programme led to a long time gap until next generation bike-sharing programmes started showing up.

Second Generation

In the early nineties, a second generation was introduced in Denmark. It started as a small-scale programme launched in 1991 in two cities (Farso and Greno). This led up to the launch of a bigger scale second generation programme in 1995, in the city of Copenhagen. The service featured specially designed, more durable bikes that users could pick up from stations with a coin-shaped token. However, the anonymity of the user base once again was the cause of limits in success. Even still, the programme, known as Bycyklen, grew quite famous, and became an inspiration to many other cities. It had a life-span of nearly seventeen years and a capacity of over 1.000 bikes, when it was finally shut down near the end of 2012. It has since been replaced by a modern system, Go-bike, otherwise known as Cykel DK, which is currently in testing phase.



Third Generation

Experience from the previous programmes, and the availability of new technologies that could facilitate the identification of the users, were major contributors in the development of a third generation of programmes. In 1996, the university of Portsmouth, England, introduced a new system, featuring magnetic cards as a token for the bikes' disposal. Third generation systems incorporated new technologies such as electronic locks, telecommunication systems, smart cards, mobile phones and computers. Growth was not significant until the Velo'v programme was launched in Lyon (France) with a capacity of 1.500 bikes, spread across the city. Velo'v is currently still running. The programme nowadays figures over 15.000 annual memberships. The real turning point, however, was the introduction of the Vélib programme in Paris on July 15, 2007. At launch, the programme featured 7.000 bicycles. Two years later, due to excessive demand, it easily figured over three times that number, with a sky-rocketing 23.600 bikes in operation across Paris and its municipalities. Vélib is, to date, the third largest bike-sharing programme in the world, with an average of 85.211 rides per day in 2011. Paris, with the successful use of bicycles as a means of public transportation, raised great interest in other cities. By the end of 2007, roughly 60 programmes had launched all over the world with more to come every subsequent year.

Beyond The Third Generation

While third generation systems introduced electronic automation, and the means to manage a large user base, we now find ourselves on the brink of a fourth generation. This next wave of sharing systems draws from experience with the existing services, to increase effectiveness and usability with improvements in, by example, solar-powered terminals, new locking mechanics, better bicycle distribution and traceability, different types of bikes and the implementation of electric pedal assistance. Bike sharing services are upgrading heavily toward this next generation of bike-sharing. "The future of bike-sharing is clear: there will be a lot more of it. Gilles Vesco, Vice President of Greater Lyon, quotes his mayor when saying, "There are two types of mayors in the world: those who have bike-sharing and those who want bike-sharing." This certainly seems to be the case as each bike-sharing program creates more interest in this form of transit—call it a virtuous cycle." (DeMaio, 2009)

ORIGINATION FIRST GENERATION 1968, AMSTERDAM WHITE BIKES





IMPLANTATION
SECOND GENERATION
1995, COPENHAGEN
BYCYKLEN

1965 1970 1975 1980 1985 19

The future of bicycle sharing, the aim of the project

Though numerous programmes are currently in a transition phase to reach this fourth generation of bike-sharing. There is no consent that one of these has yet managed to deliver a full-fledged fourth generation product. Either the innovation-factor is simply too insignificant (i.e. the implementation of but a single technology: the B-Cycle programme has recently adopted solar powered stations) or the product introduces over complicated technology at the expense of durability or cost-efficient registration fees (the fall-2013-launched Cykel DK in Copenhagen features mounted tablet computers on the bikes among other high-cost technology on the bikes, disregarding vandalism caused by the Copenhagen nightlife).

Conclusion

A true fourth generation system should introduce significant new technology, but should also pertain the strong points of previous generations:

- 1.) A low-cost infrastructure
- 2.) Sturdy and durable
- 3.) Simple and reliable use

BREAK THROUGH THIRD GENERATION 2007, PARIS VÉLIB





OPTIMIZATION
FOURTH GENERATION
2013, COPENHAGEN
CYKEL DK

1995 20

2000

2005

2010

2015

Figure 3: The four generations of bicycle sharing (Alta Planning + Design, 2012)

2.2. Service Mapping And Case Studies

At present day, most systems in operation are third generation programmes. An in-depth desk research into these programmes provides valuable information regarding user experience, current technologies used, and financial possibilities. A reference document was constructed, listing most active systems with their respective company URL. The full list may be found in "23. Appendix B: Observed Programmes" on page 174. Furthermore a mapping of service traits was made with some of the more significant services in operation.

Because of their relevance to further research, most of the major third generation networks were taken into observation. Four of those networks were chosen for specific case-studies. With the exception of Cykel DK, which exclusively runs in Copenhagen, these are all international programmes, offering their successful scheme up for sale to different cities worldwide. The purpose of these studies was to define the strengths and weaknesses of each service, chart the respective bike characteristics, and explore the possibilities for innovation.

There are only two kinds of mayors: those that have a bike sharing system, and those that want to have one,



Cyclocity

With services running in over 30 cities worldwide, the CycloCity programme is the largest, most widespread system in operation today. The service was developed by advertising bureau JCDecaux. It's a third generation programme with distinctive features such as (inter alia) specifically designed stations, smart-cards for bike disposal, lockable bicycles and limited free transport. Cyclocity is the largest, most successful sharing model in today's world. The system receives merrit for its cheap but polished service. Studying the factors of why this formula is so popular may lead to significantly better design choices, which makes it relevant to this preliminary research.

Cyclocity Bicycles

The bicycles are fairly rudimental: big city bikes with a low top tube for easy (dis)mounting. They may be locked onto their respective station by means of a large anchor on the right side of the bicycle's down tube. All the basic features are present, including an adjustable saddle, basket in the front, kickstand, bell and automatic lights with a dynamo-generator. Each bicycle also has a cable-lock attached to the head tube for short stops. The service generally employs a tight, high density network of stations, large sets of bicycle hubs anchored to the pavement. Bicycles are locked into the specified hubs via anchors on the down tube of the frame. The stations include a distinct user kiosk at which bikes can be accessed through credit-card payment or membership smart-card.

The Vélib Programme (PARIS)

"Paris's bike-share franchise contract is held by SOMUPI, a JCDecaux/Publicis partnership. Theprogram is run and administered by JCDecaux. In exchange for rights to 1,628 advertising panels on billboards and other street furniture, JCDecaux maintains and operates Vélib' and carried the full cost of the initial startup capital, around €90 million. Vélib' operating expenses, for 20,600 bicycles, are estimated to be €35 million. JCDecaux expects to generate around €50 million in revenue annually. The city of Paris receives all of the Vélib' subscripon and use fees, estimated at €30 million annually. Vélib' is overseen by Atelier Parisien d'Urbanisme (APUR), a city of Paris planning agency. First year ridership numbers highlight the immediate success of the Vélib' program. Vélib' opened its doors in July with 13,000 annual Vélib' subscribers ready to ride. By October 2007, there were 100,000 annual subscribers. As of July 2008, a year after its introducon, Vélib' had sold 200,000 annual memberships. 33% of all annual subscripon holders (~63,000 people) live in the Parisian suburbs, testifying to Vélib's power to draw commuters from outside of its coverage area. JCDecaux reported 27.5 million Vélib' trips in the first year; an average of 75,000 trips/day. During the Paris transit strike in Vélib's first winter, ridership rates reached 73,000 trips/day, more than twice the typical winter ridership. Tourists and short term members have also flocked to the bike-share system. Within the first six months, Vélib' sold 2.5 million one day passes." (NYC dept. of city planning, 2009) The programme can be safely considered the precedent of all current large-scale bike sharing networks.



Cykel DK

Cykel DK is a full-fledged fourth generation system, implemented during the fall of 2013. Despite mixed opinion about the many 'unnessescary luxuries' introduced in the bikes' design, city government beliefs that Cykel DK holds the future of bike sharing systems everywhere. Cykel DK is considered, by several experts, the first system that introduces true fourth generation bike sharing technology. From another standpoint, however, the programme has recently sparked great controversy, leading up to its launch in late October 2013, on account of its fragile bicycle parts and high price-setting. Not only do the history and current 'fourth-generation' features of Cykel DK provide a static frame of reference: the degree of acceptance, and subsequent success will definitely provide valuable information to this research. The evolution of this programme will be watched closely during the course of this project.

Cykel DK Bicycles

The Cykel DK bicycles introduce a very futuristic design. The framework is sturdy and clean, with integrated lights and a heavy-duty luggage rack to prevent vandalism. Each of the bicycles also has its own built-in tablet computer for GPS-purposes, updates about the service and railroad applications. The bicycles also feature optional electric pedal assistance.

Cykel DK In The Media

Although Cykel DK offers a whole new array of technologies, it caused a great amount of controversy in the weeks after its introduction. Opinions divise on whether the system introduces the future of bike sharing, or simply calls upon unnecessary 'gimmicky' solutions, creating a mere illusion of successful innovation. M. Colville (2013), of the Copenhagenize urban consulting bureau, made the following statement in The Copenhagen Post: "They could have copied and pasted a system that has already been proven to work. This is the grossest over-complication of a simple system I have ever seen." More criticism is due to the mounted tablets installed on the bicycles, with users questioning the safety of cyclists looking at a screen while riding through the city. The same argument could obviously be raised about automotive GPS-monitors. Some critics are of a more welcoming attitude towards the service. "I'm not sure if I've seen a bike-share technology that will truly take us into the 4th generation of bike-share, but from what I've read so far, it's looking like this could be it." (DeMaio, 2012)

Saturation

The territorial saturation, and tightness in the mesh of bicycle stations, is a critical factor of success to station-based bike sharing systems. Small-scaled city networks do not work, unless they feature a free-park system that isn't reliant on a stationary infrastructure, such as the OV-bikes programme in Amsterdam. Cykel DK's aim is 1260 bikes spread across 60 stations to cover the city of Copenhagen. It remains to be seen if the programme will be as successful as its predecessor, Bycyklen.



Smoove

Smoove is a French corporation focussed solely on the development of bike-sharing bicycles and services. The programme is known and praised for its reliability, moderate pricing, and the fact that it is not linked to any advertising deal. The company is most known as a manufacturer of bike sharing parts, rather than a full-system developer. The company offers viable components up for cities that seek to implement a bike sharing service of their own, but lack technical know-how of how to make said system operate in a fool-proof manner. The programme is heavily focussed around fundamental, yet hi-tech solutions, optimizing the usability aspect of both the stations and the bicycles.

Smoove Bicycles

Smoove Group lays heavy focus in developing cheap, light, and sturdy bicycles to reduce maintenance cost and the probability of vandalism. A key feature of the Smoove bicycle is the Fork Lock, an internal mechanism which fixes the position of the bikes' steering handles. Furthermore the bicycles also feature a self-winding cable lock, puncture proof tires, internal transmission gear by cardan-joints, rear hub gear, front hub dynamo generator and a large front basket.

Smoove Systems

Smoove offers two systems: Smoove key, an RFID key token that can be obtained from a nearby access kiosk; and Smoove Box, an integrated RFID reader on the bicycle for smart-card users with a numeric keyboard for casual users that purchased a rider's PIN online, by sms, or at a nearby access kiosk. The bike stands themselves are not powered: the locking feature is located within the bicycles front fork.



SmartBike

Clear Channel's Smartbike Programme was one of the first public bike sharing systems in operation. Its first ever service, 'Velo à la Carte' in Rennes, France, went live June of 1998. The system could be considered the precedent for the third generation of bicycle sharing. The service has known widespread growth ever since. At present day, the system runs in 13 cities worldwide.

Smartbike Bicycles

SmartBike introduces a very distinguished design for its bicycles. The bicycles are simple, tough, and very unique in shape to prevent use of stolen components. Generally, models do not include an extra locking feature. Clear Channel aims at implementing a very tight mesh of cheap stations, rendering the use of short halts in between two stops obsolete.

Smartbike Service

The Smartbike service is a rather early example of a third generation sharing service. It has seen various upgrades over the years, but should not be considered 'hi-tech'. The modular low-cost stations are equipped with a smart kiosk which users can operate using a smart-card yearpass, or a code for day/weekpass users. The bicycles' locking system is fairly unique. Two vertical anchor points sink into respective sockets of the station docks, which are mounted on a horizontal beam. An RFID-chip fixed on the luggage space of the bicycle is used to indicate whether the bike is properly returned. The stations are quite space-efficient compared to its main competitor, Cyclocity, as they allow multiple bicycles to be stored per module, often on both sides of the module. This allows up to six bicycles to be stored on a two-meter long module. The stations also require less subterranean excavation due to their small-sized anchor points, of which only two are required per station module.

The Bicing Programme (BARCELONA)

Bicing, the bike sharing network of in Barcelona, is the largest city-application of the Smartbike system. The system is the greatest competitor of JCDecaux's Vélib service in Paris. The system recieves great merit, and, like Paris, serves as an inspiration for the implantation of other metropolitan sharing services. Possible issues with this appliance is that there is no option for daily and weekly passes, eliminating any use by tourists. Further complaint comes from the limited availability of the service, which does not run past midnight, and comes back online at 5 AM. Overall, however, Bicing is a much praised service, and one of the largest models operating in the western world.

2.3. Conclusion

General Findings

Previous generations of public bike sharing, as well as significant sharing systems currently in operation, were analysed for critical factors, limiting, or stimulating success.

Proper User Identification

Fool-proof user identification is the most key factor of success for all generations of bike sharing. Users must be made aware of their personal responsibilities whilst using the bicycles, and the consequences, if they were to disregard these responsibilities.

Scale

A second critical factor is scale. Small scale bike sharing networks do not work nearly as efficiently as larger networks. They are not as flexible, and not as user friendly, as the user generally has to walk further to find the nearest station.

Implantation

As implantation takes up a decent share of initial investment for bike sharing networks, cheap stations that can be implanted faster provide great added value for an infrastructure-bound bike sharing system.

Bicycle Availability

A cricital factor of success is the availability of the service. This effect is subsequent to both the constant regulation of unbalanced stations, and the operating hours of the service. Provision crews are constantly rushing from station to station to supply these points with bicycles. In cases where service staff is severely outnumbered compared to the userbase, serious frustration about bicycle availability will surely ensue. Closing the service at night eliminates overnight use, possibly reducing bicycle related incidents, but also causing frustration among users that need a bicycle past midnight.

Bicycle efficiency

Numerous programmes promote bicycle efficiency: providing extra cargo space, extra sturdyness, or an ergonomic design. Electric Bicycles are heavily used as a marketing tool by the few systems that have yet adopted the technology.

Digital support

The digital revolution is only now reaching the major bike sharing networks. Full digital support, embedding the service's physical features into a digital platform, is of critical influence to the future of bike sharing

Power Consumption

Most sharing stations are continuously powered. Innovative sharing services make great use of green power sources, or powerless stations to generate more efficient power consumption.

Overall Conclusion

Numerous factors of success were defined in this first part of the analysis. Drawing from these observations, the next chapter of research is initiated: exploring the technical possibilities for innovation into these aspects.

3. New Technology In A Familiar System

The following chapter presents an overview of research into technological characteristics, and desired features of a fourth generation bike sharing network, and which technological innovations could meet these requirements.

3.1. Digital Complements

Mounted digital components

The Copenhagen-based Cykel DK is a programme launched In the fall of 2013. Its prime feature and greatest factor of controversy is that of the mounted tablet computers, positioned on the steering handles. The tablets may be used to track nearby stations and should provide accurate information on the availability of parking space/other bicycles. Furthermore the interactive service provides users with other data such as a real-time updated train schedule.

Full Smartphone Compatibility

There is a strong opportunity for increased smartphone compatibility. This goes beyond standard applications regarding the position of stations and the availability of bicycles. The smartphone can be used as a replacement for the third generation's smart-card. A bicycle could possibly be unlocked for the user simply by approaching it with a registered phone.

3.2. Bicycle Availability

Provision EV's

As a great operational expense comes out of fuel costs, there is potential long-term benefit to be found in the use of EV's for bicycle disposal. The electric vehicles would likely have to be greater in number as to guaranty continuous battery charge, which makes them a fairly large initial cost. The operational expenses in the long-term however, definitely provide a good return on investment. The Smoove programme is one of the few programmes that use electric disposal trucks, effectively reducing operational expenses.

Fast-Install Stations

A major opportunity for the fourth generation of bike-sharing is the fast and effective implantation of sharing stations. This is a viable opportunity for innovation, as 70% (EPOMM, 2012) of the implementation cost goes into the building of the stations. There is the development of modular solutions, where one central hub is embedded in the pavement, with bike stands coupled to this central hub with no additional excavation required. Alternate solutions include stations that are kept in place simply due to their weight-factor.

Smart-Lock

The most cost-efficient model of a modern bike sharing infrastructure is to have no infrastructure at all. Smart-lock bicycles can be left anywhere at the will of the user, and may be unlocked using a smartphone application or hotline. The bicycles are equipped with a positioning device to retrieve the bicycle for maintenance, and to prevent theft and other user-related bicycle disappearances. This locking feature makes for a network that has great flexibility. The smart-lock feature however makes for unreliable disposal. Commuters generally receive less benefit from smart-lock technology as they have no assurance that a bicycle will be waiting when they arrive. Smart-lock systems are most effective for use by residents (not so much for commuters) and in university-bound sharing systems as an on-campus transport.

3.3. Power Efficiency

Solar Power

Several services have yet made the (partial or total) transition into solar power as a source of durable energy. Solar powered sharing stations, in our society, where status and ecological solutions go hand in hand, are without a doubt a technology worth considering. Threats that need to be recognized are increased infrastructure costs for a more fragile infrastructure. Furthermore the possibilities for placement are limited as the solar cells require sufficient exposure to sunlight. New York City's recently launched CitiBike programme currently has to deal with this issue as many of the solar powered stations are positioned in the shadowy 'canyons' between the city's larger buildings. Three possible models for solar power supply are discussed below.

- 1.) Solar cells as station roofs seems to be the most practical opportunity for implantation of solar power units. Yet, it poses a number of notable threats. As mentioned above in the case of CitiBike New York: positioning of the stations is greatly limited in terms of power efficiency. Furthermore the angle of the stations will be determined entirely by efficiency of ray capture, unless a mechanical rotary system is included to continuously catch the rays at an optimal angle.
- 2.) Solar cells on a separate mast, whether on the station itself, or at a distance, would solve the issue of optimal capture at a lower cost. A (possibly modular) system of pole structures could be rotated and stretched to always capture the sunlight at the best angle.
- 3.) Solar cells, directly on the bicycles is a third possible way to supply the batteries with durable power. "Bike sharing systems are most highly subscribed during the middle of the day, when solar generating capacity peaks" (Cherry, Worley, Jordan, 2011). Naturally, the area on which rays are captured would be significantly smaller, and chances for vandalism of solar cells would likely be significantly greater.

Sleep Mode Stations

An opportunity suggested by Peter Midgley(2011) encourages the use of sleep mode stations: hubs that are only powered when they're activated by the user. The locks typically require net current only when a bicycle is docked or removed. This is the only time span in which the station is powered, making it tremendously more power-efficient than regular third generation systems. Among the observed programmes, there was only one (B-cycle) that had yet adopted this kind of technology.

3.4. The Electric Bicycle

Signature Technology

Possibly the prime technological opportunity marking the fourth generation of bike sharing system comes with the implementation of electric bicycles, or e-bikes, as they are commonly called. "Some of the goals of bike sharing include attracting casual bike riders; those who don't own bikes, commute by car, or use transit. Much of the commuter market is not predisposed to commuting by bike for a number of reasons. Electric bikes can overcome some barriers to bicycling for viable, expanded market of commuters. However, electric bikes are generally significantly more expensive than similar quality nonelectric bicycles. As such, the electric bike market has not grown as rapidly in the US as compared to other countries. Sharing electric bikes can overcome price barriers by spreading the cost over many users. Including electric bikes in a shared environment also casually introduces the technology to users without the pressure or commitment of a purchase." (Cherry, 2011)

Two Models

Christopher Cherry (2011) refers to the following models as the two most widely used electric bicycle principles.

1.) The 'Twist-And-Go' Model

The classic twist-and-go model electric bicycle is equipped with an electric motor, on either of the wheels, and a throttle controller, usually positioned on the steering handle. The user can adjust the amount of electrical power input at will, and though pedalling is possible, it is not obligatory. The bicycle, as it were, may be driven much like a motorcycle.

2.) Electric Pedal Assistance

Bikes with electric pedal assistance, also called 'Pedellecs' work through a more sophisticated mechanism. A sensor on the pedal axis continuously measures the pedal power input by the user, and feeds this information to the motor unit, which then adds electrical power, relative to the amount of force input by the user. This creates a much more harmonious conjunction between user and machine. The bicycles can also be set to reduce the amount of power input at greater speeds, providing more control over speed limits and possible safety hazards. It's also more power efficient, as the user will always be required to input manpower in order to receive electrical assistance. The reduced battery strain creates a great opportunity for implementation in a public sharing system. Less time spent reloading means more time spent on the road. For a fast-operating network with a narrow mesh of stations, reduced power consumption is a godsend.

Charging Models

There are several ways as to how the bicycles' batteries could be charged. The two most prominent would be direct charging of separate bicycle batteries, compared to indirect charging on the bicycles themselves. Direct charging (shown in Figure 4) has the benefit of being able to store a great number of chargeable batteries at a single station, increasing the chance of at least one battery being at full capacity when obtaining a bicycle. It however requires the user to insert the battery manually into the bicycle, which is not quite the signature stamp of a hi-tech network. It also opens up the possibility for battery damage or theft. Indirect charging (shown in Figure 5) is a power supply model where the batteries are always locked inside the bicycle. Users can then obtain a fully charged bicycle, ready to go, rather than a separate battery. A solution that requires less time and effort from the user. Disadvantages include a less efficient use of space, and fewer options from which to choose when it comes to charge-level of the different bicycles.

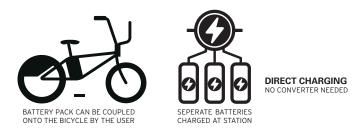


Figure 4: Direct charging model



Figure 5: Indirect charging model

Inductive Charging

While conductive charging may seem like the only viable charging technology, charging via inductive power transmission might just provide a feasible altenative. For a bicycle sharing system that supports electric vehicles, a fast, intuitive charging method is required. The charger port has to be safe in all weather conditions and should be durable enough for a long life cycle with frequent usage. A bicycle of a popular sharing service, such as Clear Channel's Velo-Antwerpen, is seeing 5 to 6 uses every day. Over a ten year life-span this figures close to 20.000 charge occurrences per bicycle. These numbers can never efficiently be met using conventional power outlets: a durable, heavy-duty charging solution is required. The possibility to achieve this standard can be found within the field of inductive charging, also known as wireless charging. "Inductive charging is a coupling process that transfers electrical energy from the electric utility charge port to the EV battery pack through an electromagnetic connection rather than physical or direct connection. Operating on the principle of a transformer, the electrical energy transfer takes place by linking the electromagnetic fields between two separate inductors. The primary and the secondary inductor are coils of conductive wire that are wound to contain the magnetic field with a ferrite material. A simple inductive coupler consists of a copper coil wound around a ferrite core to direct the magnetic field.

When electric current flows through the primary coil, the resulting magnetic field induces an alternating voltage through the magnetic field and into the secondary coil. Thus the circuit is completed. The AC current is then converted to DC and stored in the battery pack." (Dhameja, 2002)

Inductive charging offers great advantages when compared to conductive power transfer. The prime advantage when compared to conductive charging, is that electrical induction involves no direct connection between electrical components. There is no need to fit a coupler into a standardized port, no conductive pins to be connected into their respective sockets. This offers a great number of benefits when put into context of public bike sharing. First on the list is ease-of-use.

Since there are, by default, no fragile components to the coupler or the port, the user never has to struggle to connect a bicycle to a station. Increased durability of the charger is a natural consequence to this usability benefit. Another important factor is safety. The inductive charger serves as an isolation transformer. Both coils are insulated, hence any risk of electrocution that conductive charging might pose, is abolished when charging via induction. As there is no direct electrical contact, the inductive coupler and port may even be operated in wet conditions, with no risk involved. Thus a third benefit can be found in substantially increased durability in outside conditions. The system is safe and resistant in such a manner, that it even could be operated under water.

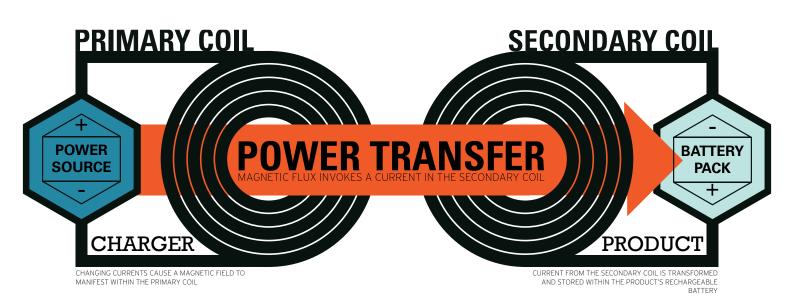


Figure 6: Inductive charging process explained (Mechanical Engineering Online, 2011)

3.5. Conclusion

Technological developments, found to be of significant influence to the future of bike sharing were researched in terms of functionality and viability.

Reducing Costs For Infrastructure

The biggest investment for a bike sharing system goes into infrastructure, and operational costs related to maintaining that infrastructure. A system that makes use of light, fast-installed, or even flexible infrastructure is the benchmark of a new generation. Stations that increase effectiveness of bicycle disposal should also be considered, as staff shortage and dependency upon provision crews for bicycle availability is a great liability in third generation networks.

The Potential Of The Electric Bicycle

E-bikes in a bike sharing service provides an economic means for users to explore the technology, and possibly lead up to growth of the electric bike market in general.

Bike sharing regions that feature a larger territorial span will benefit from the technology's ability to make rides further and faster.

Cities with steep terrain features will definitely benefit from this technology, as it makes bike sharing feasible where regular bicycles would demand excessive physical effort.

Embedment In A Digital Service

A digital platform should offer new levels of user comfort. Further impacting the lifestyle of the users, and generating improvements within the bike sharing infrastructure, and the city infrastructure all together.

A Durable Product

A next generation bike sharing service cannot run purely through net current, green sources of power should be included. Other means of efficient power consumption should definitely be considered.

4. Which Society-Based Opportunities Could Make For A Better Bike-Sharing Experience?

Bike sharing also has a great socio-cultural aspect to consider.

4.1. Real-Time Digital Tracking

Tracking Benefits

Real-time tracking of the bicycles not only gives a constant visual of the location of the products, it also greatly boosts accurate feedback on the efficiency of the stations or lack thereof, and it might help in planning further expansion of the programme, or even the city's mobility infrastructure itself.

User Comfort

Real-Time positioning, especially combined with a clear visual feedback such as a touch-screen display would greatly benefit the usability aspect of the service. Currently one of the greatest discomforts with public bike-sharing is finding a station near the desired destination, especially when already 'en route'.

Locating Bicycles

Locating stolen bicycles, or bicycles that have broken down while cycling may be another advantage to this technology. A user could simply call the service hotline anywhere, even when unaware of his own location, and a repair-truck would be on the way. This feature becomes more viable when territorial expansion takes place, and bicycle stations become more widespread.

Service Infrastructure Improvements

As a more post-event analytic benefit, tracking the routes of the bicycles will result in more accurate information about the use and trajectory-lines of bicycle traffic during the day. This causes precise information gathering about which users go where, taking which routes. If a crowded bicycle route shows a hiatus in the saturation, additional stations can be implanted exactly where they are needed.

Placing reservations

Having a 100% guaranty that a bicycle will be waiting is one of the greatest desires of third generation bike sharing users. Especially commuting users can truely benefit from the possibility to claim a ride in advance, eliminating frustration due to the absence of bicycles at critical stresspoints such as the morning rush hour. Naturally, there must always be a number of bicycles available for use by 'casual' users (users that did not make a reservation), to prevent the frustrating situation of arriving at a full station only to find out that all the bicycles have reservations on them. This can be achieved by placing only a certain percentage of available bicycles up for reservation, or by always preserving a fixed number of 'casual' bicycles (i.e. three bicycles at each station.



Figure 7: The concept of desire lines

General Infrastructure Improvements: Desire Lines

City mobility infrastructure lays down specific paths for each respective traffic user to follow. When it comes to more flexible traffic users -specifically bicycles and pedestrians- these laid out paths are not always the route preferred by the user. Often we find ourselves straight-crossing a public grass field, when there's a clear dirt walkway curving through it. This kind of behaviour may be seen as unrespectful, or even illegal. When a majority of traffic users follows a similar pattern, however, the problem shifts perspective from a user disobedience, to bad city planning. When 90% of cyclists cross a street diagonally, instead of using the zebra stripes, does it not mean that the crossing is designed in an impractical manner? Copenhagenize consulting studied the phenomenon, and codified these traffic patterns as 'desire lines' visual lines representing the preferred routes taken by the users. The agency has mapped out desire lines in various traffic situations through simple visual observation. Gps-tracking, however, could accurately provide fool-proof record of the desire lines created by all of the bike sharing programme's users. Results of these records may provide valuable information, not only regarding the current mobility infrastructure of a city, but also how the users would see it improved. Figure 7 is a situational sketch, illustrating the concept of desire lines. Traffic infrastructure guides users over a 90° corner, but cyclists and pedestrians will generally take the desired course which cuts the corner, and is therefore more direct.

4.2. Bicycle Helmets

'To helmet or not to helmet'. The question has been asked more than once in the context of bike-sharing. When implementing the electric bicycle into a sharing network, it may seem almost obligatory to include helmets within the programme. However, previous instances of bicycle helmets being used in sharing services, and cycling in general, have been subject to controversy on frequent occasions. The following chapter discusses the use of bike sharing helmets for bike share bikes.

Previous Experience

There have been cases of bike sharing programmes promoting shared helmets, or providing a free helmet when registering. The success of these campaigns is usually limited, especially in the case of shared helmets, which the majority of users deemed 'quite gross'. There might also be a deeper sociologic background for the unsuccesful campaigns with bicycle helmets. "Australian projects, like those in Melbourne and Brisbane, require riders to wear helmets. That's been a turn-off. Despite having the same technology as New York and London, those systems have been really quiet unfortunately, because they fine people for not wearing helmets. Bikes there have been used less than once a day, on average, compared to an international norm of up to eight trips a day. The cities are now giving away free helmets, and Brisbane is considering relaxing the rules in some areas." (Co.Exist, 2013)

Mikael Colville-Andersen On The Subject Of Bicycle Helmets

In numerous lectures, mr. Colville-Andersen, co-founder of Copenhagenize Urban Consultancy and great promotor of urban cycling, preaches heavily against the use of bicycle helmets. The bicycle helmet scientifically doesn't have an impressive safety record. Research on the subject has left the scientific community split in half. Colville-Andersen states "There are scientific studies that show you having a 14% greater chance of getting into an accident with a helmet on." (TedxTalks, 2010) Furthermore the helmets are often tested only for full frontal impact on the crown of the head, these tests are in fact merely a simulation of front-falling on the curb while walking. An actual bicycle is rarely used in the test-environment. Mr. Colville Andersen also states that "Pedestrians actually have a greater chance for head injury than cyclists. Strangely I found no safety regulations for pedestrian helmets."

Bicycle Helmets In A Culture Of Fear

Did the introduction raise safety concerns about the project? Indeed it did. This feeling could be defined as the helmet-effect. The bicycle helmet is a nearly obligatory safety measure that has become increasingly embedded in our society, where fear is often used as a selling point. The promotion of helmets, however, works as an opposite force to the popularity of cycling itself, and actively reduces bicycle sales. Helmets are promoted as a relevant, possibly even obligatory, bicycle accessory. This is the worst kind of branding that the fundamentally green and possibly healthiest mode of transport could receive. When reaching

for the bicycle, the user should not continuously be faced with any safety-risk involved, but rather be encouraged by the social engagement that it brings, as well as the health- and finance-related benefits. A bicycle sharing programme should possibly not even be promoted using helmets as a marketing tool (i.e. poster models wearing helmets while using the service). The safety aspect may be perceived as beneficial to the programme, but it is actually not. It is a form of negative branding, placing focus upon the safety hazards of cycling rather than factors such as fun, healthy exercise and eco-friendliness. "The health benefits of bicycle sharing are 20 times greater than any risk involved." (Copenhagenize, 2009) A positive brand should be established, and not by focussing on the possible safety hazard, which is significantly less than the risk of critical injury while driving a car. Why doesn't the automotive industry use helmets? -They're just as relevant on the inside of a car as they are on a bicycle.- Because car brands realize that it would make for bad marketing. The helmet carries a social stigma and not just that. Willingly using the helmet as a marketing tool is like willingly pasting a 'Smoking kills' label on a pack of sigarets. Bicycles should be branded in a positive manner. "Cycling is fun, socially engaging and healthy for you and those around you." Those are the arguments that will make society embrace cycling as a brand.

How Fast Is Too Fast?

The introduction of electric bicycles, which generally reach speeds up to 20 km/h without effort, raises questions about traffic safety. Although chances of fatal accidents are still fairly limited (illustrated in Figure 8), the bicycles will have to be properly configured to prevent injuries caused by inexperience and/or ruthlessness among the userbase. As presented in Figure 9, a system that introduces electric pedal assistance could be monitored to reduce electrical input when reaching higher speeds. The sensor responsible for monitoring electrical input could also be connected to a smart component which recognizes new users, and reduces the 'max-speed' even further during the first number of rides to ensure a friendly learning curve.



Figure 8 : Pedestrian injuries at impact speeds (Copenhagenize, 2013)

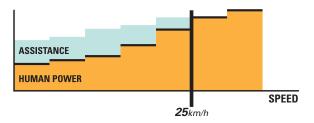


Figure 9 : A possible model of pedal assistance relative to user input at different speeds (Electric Bicycle Guide, 2012)

4.3. Cargo Space

Opportunity For Additional Space

One notable issue with third generation bike sharing as opposed to other means of public transport is that of cargo space. Studies (Copenhagenize, 2013) show that people are most incentivised to ride a bicycle for transport when they go out shopping. The problem with the average bike-share bike is that it doesn't provide adequate space for a larger shopping bag, or even a week's fill of groceries. There is, without a doubt, great opportunity for innovation when it comes to luggage space.

Cargo Bikes

Cargo bikes could provide a solution for the storage issue. The bikes might be a kind of premium service among regular bicycles, placing a small number of special cargo bikes next to a large number of regular bicycles. The number of cargo bikes could be larger at strategic places such as shopping streets, public transit stations, or supermarkets. Cargo bikes are definitely the most efficient when it comes to greater bicycle luggage storage. Threats may include the social stigma caused by the weird shape and clumsy handling of the bicycle and the greater possibilities for vandalism. The manoeuvrability of a cargo-bike structure is also significantly decreased in comparison to the regular bicycle. While this poses little to no threat in large, spatial European cities such as Copenhagen or Vienna, the narrow streets of an ancient city centre such as Antwerp may prove to be more of an issue.

Tricycles

Another alternative to increase cargo space could be to introduce three-wheeled bikes, otherly known as trikes. B-cycle is the first ever service to use trikes, with decent success. Similar to cargo bikes, however, trikes suffer the threat of social stigma, possibly even more so than the cargo bike solution. The structure however, will likely be sturdyier than a cargo bike variant.



Figure 10 : The ELF-Cycle: cheapest, lightest and most popular covered bicycle on the market to date (Phys. Org, 2013)

4.4. Covered Bicycle

The Bane Of Bicycles

A downpour: the oldest adversary of cyclists on the northern hemisphere. A little rain can easily squelch any incentive for cycling even before one sets foot outside the house. This problem is one of the prime issues that diminish the popularity of bicycles. So why, after nearly three centuries of cycling evolution, is there still no dominant solution to this problem? Covered bikes are trying to win their place in the bicycle market for years on end, and yet the majority of users seems to prefer the regular model. The discussion below sheds light on the opportunities that lie ahead, and the many subsequent threats that they bring.

Great Possibilities

There have been numerous projects on the design of a commercial covered bicycle, some to greater success than others. The most widespread model up to date is the ELF (displayed in Figure 10 on page 53), a project which had its start-up funded by the community platform Kickstarter in january 2013, signifying that there is an existing user need for this kind of solution. The ELF cycle is a covered electric bicycle that runs on pedal power and a rechargeable battery power source. Solar panels are integrated into the roof for additional power supply. The bicycle has a luggage space compareable to that of a cargo bike and provides the user with limited rain cover through its windshield and overhead roofing. The ELF is fairly popular in comparison to other cover bicycle models, mainly due to its simplicity of use, and low price-setting (\$5000 excluding service costs).

Numerous Problems

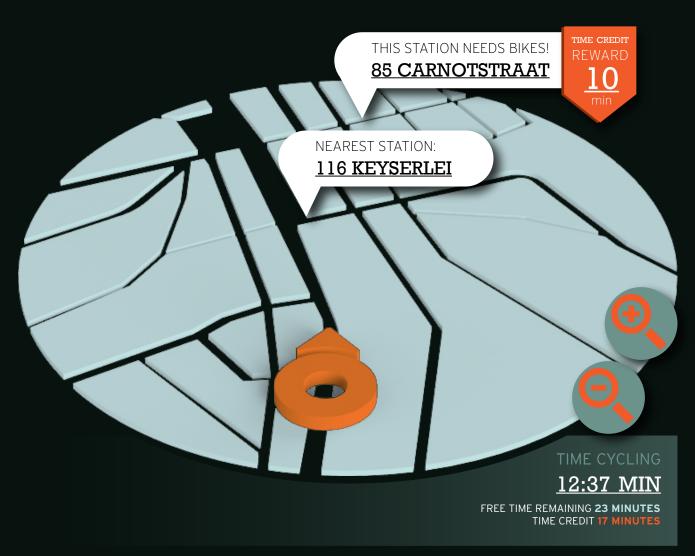
Even if a bicycle such as the ELF marks the start of a revolution in the field of cycling, the journey is far from complete. Several issues are present that douse private buyer incentive and rule out the use in a public model entirely.

- 1.) The first issue is weight. Referring back to the ELF, one of the lightest existing models: the bicycle has a mass of 70 kilograms. Not only will the weight factor be a cause of great user frustration when it comes to lifting the bicycles, it also cripples regulation entirely. "Regulators load and unload roughly 30.000 bicycles each month" (Velo-Antwerpen, 2013). The use of covered bicycles would mean a total revision of the entire system, if at all possible.
- 2.) A big bicycle requires a big infrastructure, a covered bicycle is significantly less flexible than a regular model. It cannot level higher curbs with ease, it's not allowed to ride on the sidewalks, and it cannot squeeze between cars stuck in traffic. Especially in old city centres, where the streets are often narrow, bicycle infrastructure is shy, and traffic is dense, the covered bicycles provide little to no mobility benefit compared to cars.
- 3.) When it comes to public bike sharing, vandalism is an issue to be reckoned with. In order to make a covered bicycle model cheap and manoeuvreable, the lightest materials must be used, compromising the life cycle of the bicycles when placed in the public eye. The bikes would suffer heavily from the city night life.
- 4.) Public bicycle networks are successful because they support cheap, and compact infrastructure. A covered bicycle takes up about three times the space of a regular model, either increasing the space occupied by the stations themselves, or reducing the available space for bicycles on the stations.

4.5. Push And Pull Stations

A great opportunity for the fourth generation of bike sharing is user-driven disposal. Vélib is one of the few networks that have yet adopted a system that incentivises users to assist in the balancing of stations. A city such as Paris -with decent shifts in terrain- faces issues in the popularity of certain uphill-stations. To counter the issue the programme has launched its 'V+'-concept, to encourage greater use of these stations. Users are given an additional 15 minutes to reach these stations. "Luud Schimmelpennick, a co-inventor of the bike sharing concept, reports the operational cost of JCDecaux's distribution of bicycles is about \$3 each (Schimmelpennick 2009). He believes paying customers for distribution to stations that need more bikes, either through providing a customer credit towards future use or paying the customer outright, would increase distribution efficiency at a fraction of the present cost." (DeMaio, 2009) In Figure 11, a visual impression is displayed of how the user may be employed for community driven regulation with this mechanic. Using extra free-ride time as a reward, the user will be incentivised to place his bicycle at an empty (or nearly empty) pull station, instead of using the nearest available station.

Figure 11 : Envisioned positioning/disposal while riding the bicycles.



4.6. Conclusion

Society demands were explored for opportunities from which innovation could be drawn. The research also provides a number of insights that should be regarded during the design process.

Reliability

Reliability provides the ease of mind cyclists experience when using the service. Reliability is one of the major issues that have to be handled carefully in the subject of bike sharing, and many opportunities for innovation lie ahead, such as using the community as a means for more efficient bicycle provision, and the option of a GPS display on the bicycles. Reliability of the product is one of the most significant aspects - if not the most significant - where innovation can be achieved, even with relatively low impact on the current infrastructure. It will definitely be carried into the later phases of the project.

Safety of the product

A feature which must not be disregarded, but at the same time it should not be overstated, is that of traffic safety. It can be concluded that safety, when overly promoted as a feature, may lead to bad branding and subsequent limits in success. The safety of the bicycles should be passive, an assurance that needs not to be confirmed by obnoxious visible features such as obligatory helmets.

New Bicycle Types

There is definitely an opportunity for specialized bikes with an extra cargo option, or even a roof structure for weather protection. The critical factor is if they will fit in this particular project, with the present infrastructure and monetary possibilities. When more durable, light structural elements are made available, the price of materials has lowered, infrastructure has broadened, and street crime reduced, then covered bicycle sharing will likely make for a viable product candidate. For now, however, many impeding factors prevent the implementation of covered bicycles to reach its full effect. For cargo bicycles, the main threat lies in the small size of the target market. Users will stick to regular bicycles unless they're carrying heavy loads. Other cargo solutions, such as a slightly larger luggage rack, or the option to attach bicycle bags/ a bike trolley might lead up to better results at lower investment cost.

5. Field Research: The Third Generation Clear Channel Programme

5.1. How Does It Work?

Setup

After registering on the service website, a personal annual membership card is sent to the aspiring user, to arrive within the next ten days. Once this user smart-card has been received, it should be activated using a web URL sent to the registered email address, the activation key is included on the front of the card.

Using the service

When the user has the incentive to use the service, he can first check the service website or smartphone application for stations near his current location, and that of his destination. The user then walks to the chosen station and sees if bicycles are available. He swipes his personal smart-card in front of the reader on the station's respective kiosk. Upon identification, the display on the kiosk displays the bicycle number of the bicycle to be used. The station docks also have a light feature which starts flashing once a bicycle is selected.

Upon undocking the bicycle, the user first checks the bicycle for visible defects. He then adjusts the bike saddle to match his personal preference. These are time-consuming actions. The user may then ride the bicycle to a station near his destination. When cycling in unfamiliar city zones, looking for a station is perceived very uncomfortable, especially when there was no preliminary online check for nearby stations. The visibility of the stations is also significantly reduced at night, rendering the search all the more difficult. Upon arrival at a station the user places the bicycle back into any available set of lockers. This action requires some physical effort and cannot be done with one hand. To confirm that the bicycle has been returned correctly, the user swipes the smart-card once again at the station's kiosk. Users often forget this action, or refuse to walk the distance back to the kiosk.

Personal findings regarding the bikes, as a result of user-testing the service, are documented on page 62.

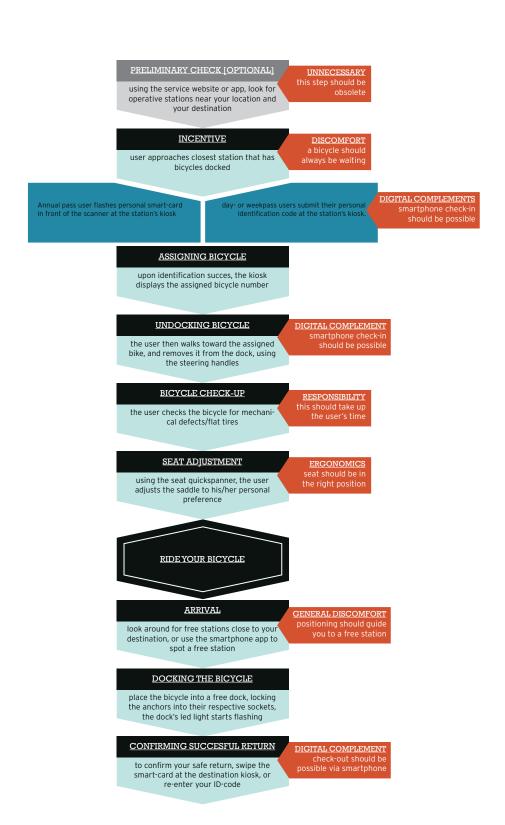


Figure 12: User interactions for a singular use of the Velo-programme

5.2. Mapping Out Bicycle Provision

The Regulators

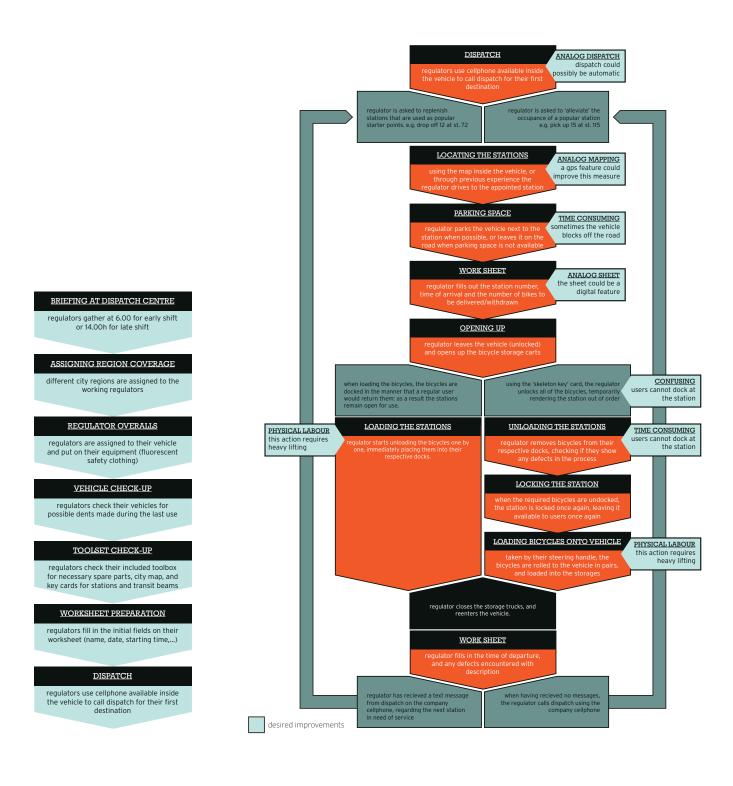
In order to keep the service balanced, avoiding overpopulated or empty stations where possible, 5 regulation-vehicles patrol around the city of Antwerp from 6 AM til 10 PM: two 8 hour shifts a day, roughly 18 stations visited per shift. These workers, reffered to regulators, lift as much as 30.000 bicycles per month. Field research regarding disposal of the bicycles provided relevant insights to the workings of the world of bike-sharing behind the screens. The regulators start their day in the front office, running through a short briefing presented by the dispatch crew. During this initial brief, regulators are assigned to a city region, and the vehicle with which to cover said region. After the briefing, regulators put on their safety clothing. Next, they move toward their assigned vehicles for a check-up. Any newly found scrapes and dents are made note of. The regulator then continues to check up on his toolbox, where a number of small spare components (bells, straps and bolts) should be present. After checkup each regulator enters his respective vehicle, and fills in the necessary data on the assigned worksheet (Name, vehicle, time of departure and any defects noted). He then calls dispatch for information about the first station that needs balancing. In almost any subsequent brief, dispatch itself will contact the regulator via text messages on a company cellphone included in the vehicle. After dispatch briefs a station to be supplied, or emptied (e.g. 'st87, pick up 13 bikes') The assigned regulator uses a paper road map to spot, and drive to the site. Upon arrival at the designated station, the regulator fills in current time and station number, and the number of bikes supplied/ picked up.

Station Balancing

When loading a station, the regulator leaves the vehicle and opens the bicycle compartments. He then starts unloading the bicycles, one by one, and docks them in empty station slots. The station remains open for use during the process. When a station is emptied for bicycles, the regulator opens the bicycle storage compartments. He then uses a special skeleton-key smart-card, which closes the station for users, and unlocks all of the bicycle docks. The regulator then proceeds to remove the required number of bicycles from the station, leaving the bicycles standing next to the station beam. When all the necessary bicycles are removed, the regulator opens the station, making it available to users once again. He then starts loading the removed bicycles onto the bicycle storage compartments.

Dispatch

Upon reentering the provision vehicle, the regulator fills in time of departure and possible defects on the bicycles. He then checks up on the cellphone if any new messages have been sent from dispatch. If not, he calls upon dispatch for his next brief. Personal findings, as a result of user-testing the regulator-shift, are documented on page 62.



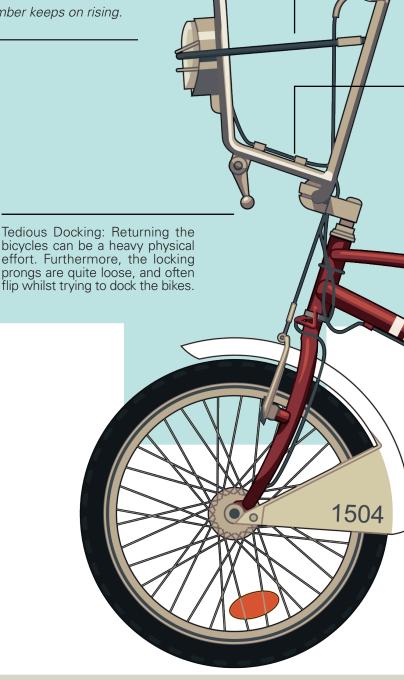
 $\textbf{Figure 13}: \textit{Regulator interactions during the preparation process, and a singular iteration of bicycle \textit{regulation} \\$

The Status Quo

Since 2011, Velo-Antwerpen provides city residents with a clean alternative for regular transit around the city centre. Rougly 1800 bicycles are available in the streets of Antwerp at this time, as well as 3600 possible docking stations. An estimated 27.000 passes are sold every year, and the number keeps on rising.

The following spread presents an overview of general information, as well as issues encountered whilst using the velo-antwerpen bike share service. While some of these findings may seem of little importance to current users of the programme, they present viable opportunities for innovation that could lead to a better, more effective generation of VELO-bicycles.

3,69 EUR
3,99 FUR
36,99 FUR
36,99 FUR
4 HRS



POSITIONING

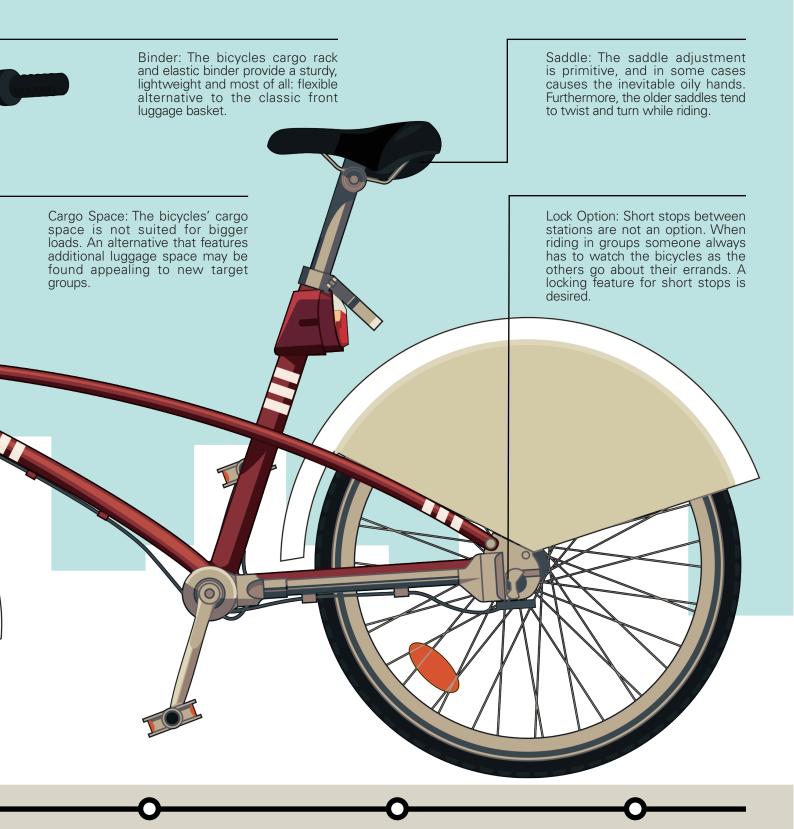
The stations are difficult to find when first riding to an unfamiliar location. This can be helped by checking online, or using the MyVelo-app, but both features are impractical when riding. The user should be able to check his location also whilst on the bike itself.

AVAILABILITY

The stations are often full when returning a bicycle, or empty when acquiring one. Station balancing may definitely be improved. This may be done by optimizing regulation efficiency or more accurately adjusting capacity of critical stations.

HARD TO SPOT

The stations are subtle, and quite hard to spot at night, especially when no bicycles are stored. A simple, iconic light feature that serves as a beacon could fix this problem.



TRAFFIC ISSUE

Regulator crews often find themselves stuck in traffic. This can be considered a waste of man-hours and fuel cost. Other less traffic-dependant regulation measures, or a general decrease in the need for regulation may provide a solution .

PARKING SPOT

Finding a place to park the provision vehicle is often impractical. The vehicle regularly ends up in the middle of the street, blocking passage for other traffic during the regulation process.

BIKE WEIGHT

The bicycles are heavy to lift, and have to be handled one by one. This makes for a slow, impractical regulation process.

5.4. Velo-Antwerpen: Estimated Shifts In User Demographics

Velo-Antwerpen is mainly aimed at commuters. The service is implanted to bridge 'that last mile', a flexible form of public transport from the train station, public parking, or even a busstop, to the office. There are lots of little distance gaps that require a bicycle, too short for public transit, yet taking up too much time when walking. Needless to say the current majority(63%) of users right now are in their twenties, or thirties. This target group is still far from saturated, and the demand curve for year-passes is still growing steady. This leads up to a few possible scenarios for expansion into the late majority. Opportunity for expansion lies beyond the Antwerp city centre. The management of Clear Channel Belgium has plans in the workings to broaden the network, hoping to eventually cover the entire city district. Users in these regions may become incentivised to adopt the

service for trips to and from the city centre, where they now prefer the bus or other means of transit. This expansion will benefit greatly from the use of electric bicycles. Electrical assistance makes trips faster, and less physically demanding. Especially for commuters who want to avoid transpiration upon arriving at work, or young elder commuters, of which we will be seeing more and more in the near future. When expanding the reach of the tight-meshed infrastructure, may (at least in the early phases of expansion) lead to more spatial station placement, with longer distances to cover in between stations. Same as in the above: electric bicycles will be a much demanded alternative to the regular service. There are a few options when branching out to new target groups for Velo-Antwerpen. One would be to target shoppers, people who carry around more luggage than the

average commuter or tourist. Shoppers could transport a big load of goods or groceries safely from the store to i.e. their home, or to a nearby train station. Electric pedal assistance, as a surplus, could potentially cause a shift in user

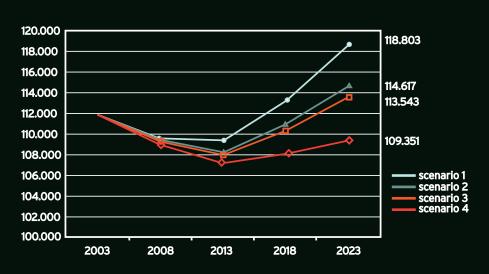


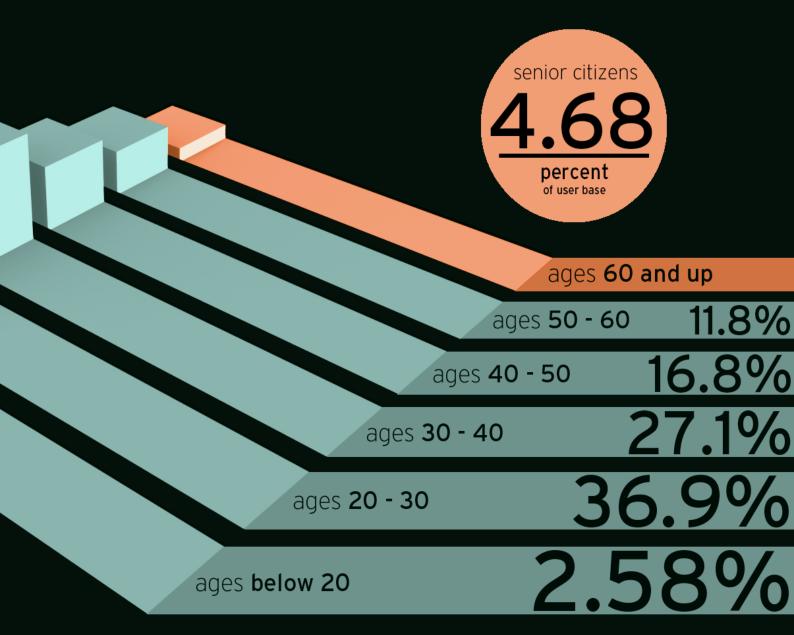
Figure 14: Estimated shifts in the elderly population figures (Department of Population Antwerp, 2007)

Figure 15: Velo-Antwerpen user age demographics (Rondeaux, 2013)

age demographics. The current system has but a small minority of users over 60 years old. Offering electric bicycles for rental at an affordable price may cause the 'younger elders' to adopt bikesharing where the regular models could

not. Statistics on the incline of elderly population within the city district are quite divided, however and display little increase in an already small number. Another matter to consider is that the elderly commuters may still prefer a

traditional form of transport. The service should however be accessible to young elders, who will still be taking part in public transport as commuters, due to retirement age increase within the span of the next 20 years.



VELO ANTWERPEN USER AGE DEMOGRAPHICS [age unspecified - 0.09%]

5.5. Userbase Stakeholders: Part-Fictional Persona's

The Busy Bee

Suzan is a happy mother of two. She's 48 years old, and has recently quit her old job due to career advances of her husband, enabling her to spent more time around the house. She lives in a quiet, rustic village where there aren't many places of interest for a smart-minded middle-aged adult. Hence she often takes the car and drives off to the nearest city. As she finds herself touching 50, she wants to be busy doing the things that she couldn't spare time for whilst still working. Aside from her various household obligations, she can now spent her time pursuing creative ambitions, which include writing for short films and freelance copywriting. She is big into reading, and often spends her time looking for intriguing literature in the many bookstores spread around the city.

Suzan is a proud owner of a Smartbike membership year-card for roughly 2 years now. She loves the flexibility that the bike sharing network has to offer, and regularly makes use of the service on one of her frequent trips to the city.

On these trips she often cycles along a certain patterned route, filled with little stops at different locations around the city centre. Generally, she will first drop off some books at the public library, then she will ride off to the store to check if her ordered items came in, she will often make a short stop at i.e. the apothecary to make small household purchases, and near the end of the day she often passes by the appartment of her sister, to check if anybody's home, and if so, if she wants to get a drink.

All of these errands can be categorized as short stops, that take up little time. More often than not, Suzan will get off her bicycle, and be needing it again over a time span of less than two minutes. Which means that she has to walk back to the nearest station, where she has to wait for the five-minute delay to pass, before she can take out another bicycle.

Suzan is part of a target group that will benefit greatly from an extra locking feature installed on the bicycle. Instead of having to ride up to a station, and then having to wait for the 5 minutes to pass, she can just lock the bicycle, make a small purchase, a delivery, or check up on a friend, and hop back on with no delay, or walking distance to be covered.

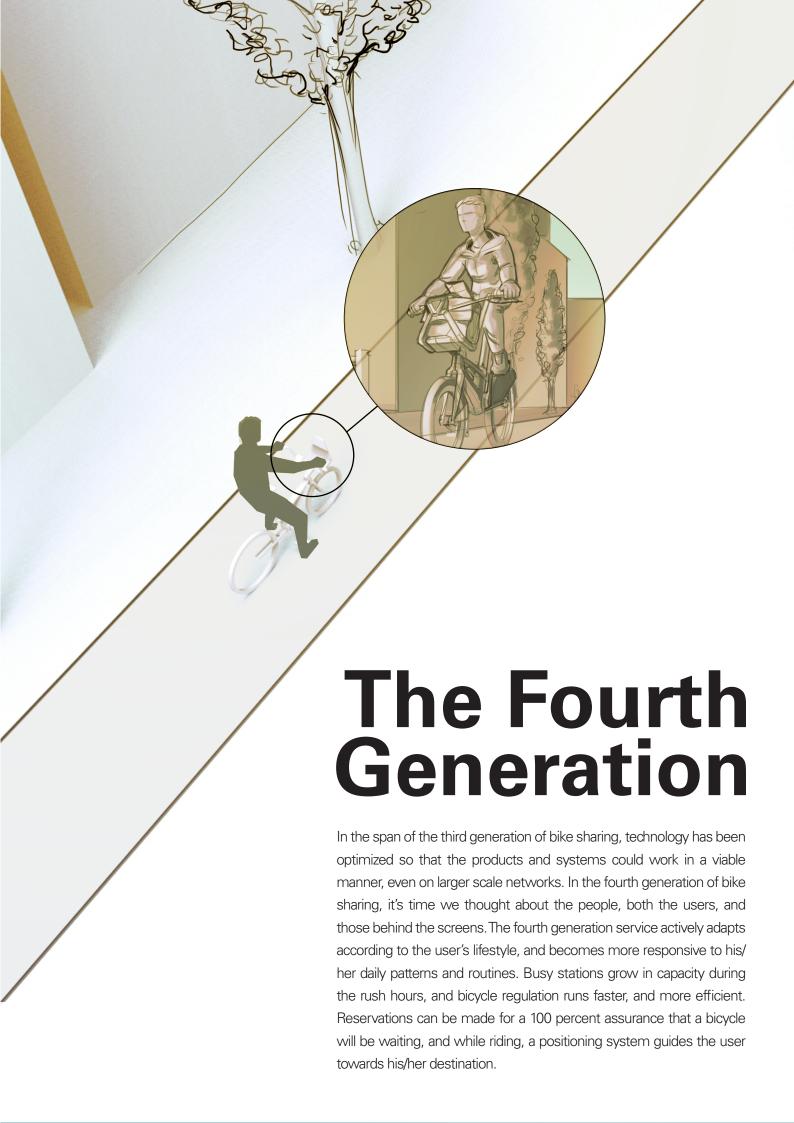
The Unlucky Commuter

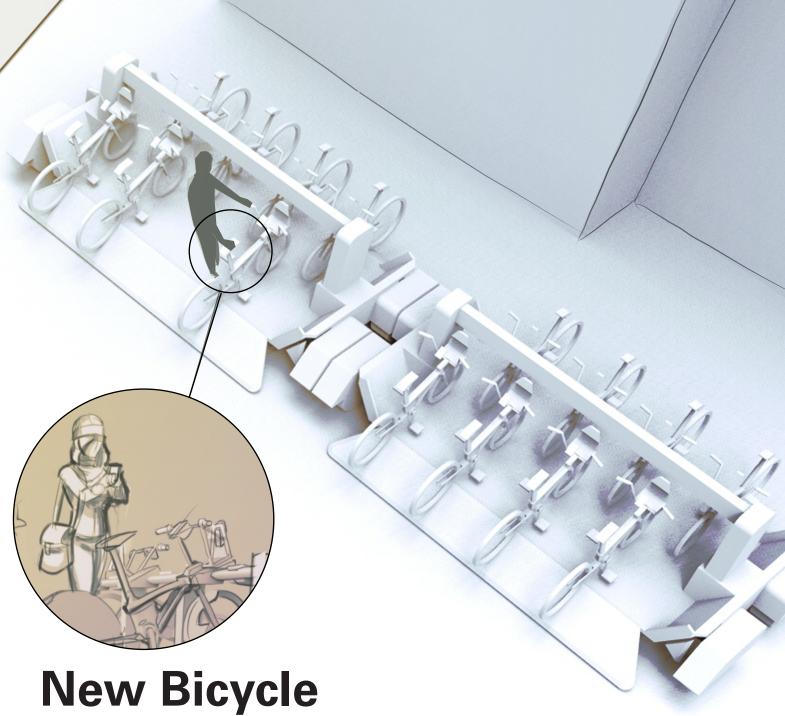
Michael is a 28 year old cleric at a clothing store in the city centre. He lives right outside the city district. Together with his partner, he rents the old house of his grand parents, who have recently moved to a retirement community. Despite having a driving license, he does not own a personal car. He is thus a full-week commuter, travelling by train, a 10-minute trip, 5 of which are stops. As a means to bridge the distance from the station to the working space, he's recently started using the Smartbike bike sharing programme. Although he's quite enthousiastic with the service flexibility and user features in general, there are returning situations that cause him frustration, especially in the morning hours.

He works the early shift, from 8.30h to 16.30h. This means travelling in the midst of the commuter rush hours. Besides often being late due to train delays, he tends to find himself at the closest bike-sharing station, which then turns out to be completely devoid of bicycles. The same thing happens in the later hours of the day. As the evening rush hour starts, the busy shopping streets quickly drain the bicycle stations. This means that Michael has to walk to the next best station, which means to back-track his steps past his working location. In rare cases this station is also found empty.

Commuters like Michael are big stakeholders for a system that has the feature of bicycle reservations. Using reservations he can easily plan ahead, securing a ride to the station, and peacefully round up his work at the store. Better community driven disposal would also improve the situation, specifically in the late afternoon hours.

An additional, radical improvement could be the placement of an e-bike station in his neighbourhood, granting him the benefit from the fast and flexible e-bike sharing system in the way that he would otherwise have to wait for the train to come in.





A next generation bicycle with electric pedal assistance, fit for long distance travel. It fits the current line of products, but introduces significant new technology and user comfort.

Digital Platform

A better digital platform will offer addional user comfort. Keep track of your rides and current credit, report defects with greater ease and make reservations for a bicycle at a station of choice.

Dynamic Station

A flexible station, that can increase, or reduce in size according to hourly user demand. The stations do not require implantation and can be mobilized for fast regulation of a great number of bicycles.

6. The Concept

The concept is a holistic design for a bike sharing system. It will touch on the interests of both the cyclists, the service, and even the city in which it is implemented. Resulting from the findings of new products planning, the different aspects of the design may be categorized according to three major actors, three major touch points, each of which must be examined thuroughly during the further course of the design.

6.1. Product Features

A Better Bicycle

The next generation of bike sharing introduces a new kind of bicycle. These bikes will be equipped with electric pedal assistance to cover longer distances in less time. The bicycles feature an accurate positioning system, guiding the user safely to the nearest available station. The feature also prevents theft, and allows users to signify their location, should there have been a critical problem while riding. A locking feature will be included, allowing users to make short stops at will, instead of having to search for a nearby station.

A Dynamic Station

In the next generation of bike sharing, the service actively adapts to the lifestyle of the user. During rush hours, stations at public transit terminals are bigger, supporting the heavy demand for bicycles. During christmas season, popular shopping locations see their closest stations grow to meet the capacity required by the many shoppers. The dynamic station consists of a number of modules, with each module having a limited capacity of bicycles. When a station nears depletion, disposal switches out empty modules with full ones, without ever having to touch a single bicycle. Filled modules can be added to stations where demand is high at a certain point during the day. In a similar way, empty modules can be temporarely added to stations that are favored as a drop-off point for bicycles. The station requires little to no implantation, and severely limits the time required for bicycle regulation.

Digital System Enhancements

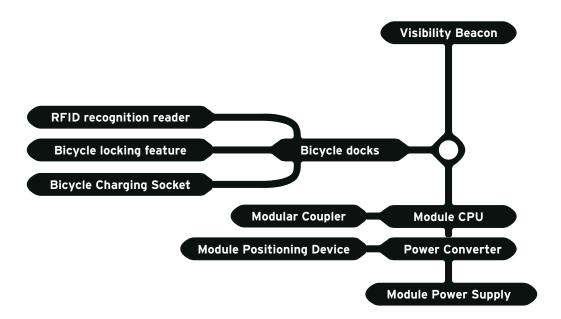
Community driven disposal is a feature that will hopefully increase the balancing between different stations. Similar to the model in Paris, users will be presented with push and pull stations, only in this case, the mechanism will shift in real-time, according to the needs of each particular station at each particular time. On their positioning device, users will not only be able to see the nearest stations, but also stations within walking distance that require bicycles. If a user stores his bicycle at one of these pull stations, he will be rewarded with time credit. When making a reservation, users will be presented with a similar offer: stations near their station of choice will be shown as optional choices, with the respective time-reward if the user decides to shift the reservation to one of these push stations. Time credit functions as a buffer that prevents the user from losing real money when overpassing the thirty minute mark by small amounts. When those free first thirty minutes have passed, you will first consume your available time credit. This counts as additional free time. Only after your full Time-Credit is consumed, will the first paying 30 minutes start, to be charged to your account. This provides a synergy with the on-bike locking system discussed in paragraph "A Positive Future Image" on page 79. Since users will be making more short stops, especially in areas with lower mesh-density, users will more frequently deplete their free half hour by cause of unexpected long shopping lines or underestimating travel distance. Hence the incentive to build up Time-Credit. Users will also be able to make reservations on bicycles, up to one hour in advance. This feature will be of great comfort to commuters, who answer to a strict time schedule, and can't afford the



Figure 16: Sketched quickdesign of the bicycles' form factor, visibly reflecting the Clear Channel line of products

6.2. Product Architecture

An early product architecture was devised, to create an overview mapping of the different viable opportunities for innovation. The nextgen concept should be hi-tech, but simple. Offering an array of new functionality, but remaining easy to use. Not all the presented systems will be carried over into the materialization phase during the term of this thesis project, as the workload would exceed the time span of the project. A closer focus on certain critical systems will be inquired in conjunction with the partners of the project.



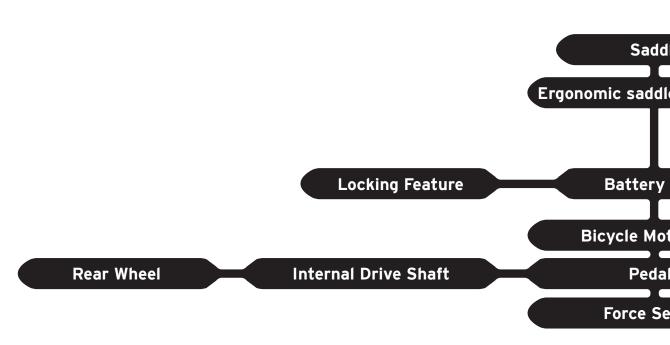


Figure 17: Envisioned product architecture of single station module

The Station Module

The station's overall design is still fairly ambiguous, but the proposed architecture does include the critical features that should be incorporated within the nextgen station. Station modules should be coupled to other modules and subsequently be recognized as a singular station unit. A quality coupling mechanism should be incorporated. The module should also be able to dock and charge a certain number of bicycles (currently estimated to be six bicycles) A bicycle recognition feature, and charging couplers equal to the number of docks should be incorporated. Furthermore, stations should be visible over long distances, even at night. A beacon feature should be included. Finally, the modules will likely run on a battery power source. This means the module will require a charger of its own.

The Bicycle

The bicycles will be equipped with electric pedal assistance on the transmission assembly. Other notable system features include an improved saddle adjustment assembly for ergonomic cycling comfort, the electronic lock for short stops, the battery pack, which is secured inside the frame of the bicycle, a GPS-tracker and display for positioning purposes, and the coupler through which to charge the batteries from the station. This mapping is a first attempt at framing the project. Although it was longtime considered to be the main project scope, the bicycle now carries equal importance to -or possibly even less- than the required infrastructure. A concept will be generated for an ergonomic, sturdy design with selected features included, but in the materialization phase the bigger focus will be the coupling mechanism to dock bicycles at the dynamic stations, which carry a more significant factor of innovation.

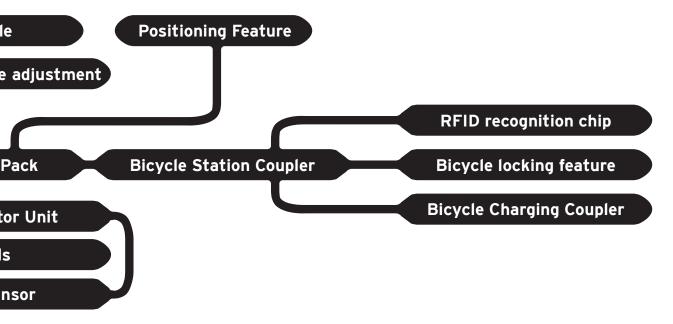


Figure 18: Envisioned product architecture with significant new features of the nextgen bicycle

6.3. Added Value

New Bicycles

The bicycles will be more comfortable and attractive to new users through the implementation of additional features relevant to user demand. These features include onride positioning, a function that the current generation does not properly support despite great user demand. A second feature is an onride locking option for short stops while riding. The bicycles will feature electric pedal assistance which allows the exploration of new user demographics and opens possibilities for expansion to wider regions and cities with more difficult terrain features.

Dynamic stations

Possibly the most significant factor of innovation will be the introduction of dynamic stations. These stations do not require implantation, eliminating an incredible part of initial investment. Regulation works in a more responsive, and efficient manner. Stations can grow and shrink their size in a direct reaction to user demand, which diminishes the overall number of powered stations needed to supply a reliable infrastructue. It greatly also diminishes regulation cost through the increased efficiency in bicycle provision and automatisation of the bigger part of the process.

Digital platform

A digital platform will introduce new features such as the option to make a reservation at a certain station, increasing reliability and user friendliness of the service even further, especially during the rush hour. Reservations will also help predict reauired capacity of stations before they are emptied by users. User driven regulation will be stimulated using the digital service, granting users time-credit benefits bound to their account for providing empty stations with bicycles, or making reservations at an overpopulated station.

Overall benefit

In conclusion, it may be concluded that the fourth generation system will introduce significant benefit to the user, the service, and as a consequence the traffic fluctuation of the city itself.

6.4. Items To Be Developed

- 1.) A modular bicycle station that does not require implantation or trenching of any kind.
- 2.) An efficient provision vehicle concept, that can handle bicycle disposal at significant financial benefit in operating costs. (This presumes of course that the station modules will not be the vehicles themselves: At this point in the design process it seems that keeping modules separated from the regulaton vehicles is the more economic solution.)
- 3.) A quality ergonomic e-bike concept fitting the current product line, emotionally appealing to users, and sturdy enough to actively reduce annual maintenance costs.
- 4.) A system design for a digital supportive platform for both service purposes and increased user comfort.

6.5. Project Verification

The product and system presented as the result of this preliminary research are feasible as they invoke financial benefit to the service, mobility benefit to the city and greater society appeal for both the service and the cityscape.

Product relevance

This product is a response to the several needs and desires presented by the userbase, as well as the service itself. It is therefore a relevant innovation in the field of bike sharing.

Technical Feasibility

This product makes use of contemporary technology where necessary to actively increase usability in a cost-efficient manner.

Financial viability

Presented in the chapter "Estimated Financials" on page 84, are the financial data resulting in both the estimated financial benefit to the service, and the user fees translated from this financial benefit.

Significant Innovative Character

Added values are generated for the user, the service and the city as a whole. The product therefore is a relevant improvement to mobility infrastructure with significant innovative character.

Opportunity for growth

Although the project is centred around the city of Antwerp for the purpose of this thesis project, the product can be sold all over the world. Bike sharing is a trending business, experiencing viral growth. Many cities in Europe have adopted, or are looking to adopt a third generation system, but a full fledged fourth generation system -which brings a futuristic look to the cityscape at very economic pricing- has great potential for transition from older systems. Furthermore, the Americas are still an open market to the world of bike sharing, which is only now spreading to the United States and Canada. Because of the mobile character of the stations, the service could just as well be seasonal, such as the Bixi programme in Montreal. The programme could even be installed with a leasing formula if desired. It's a product of many possibilities



7. Design Drivers: Introducing A New Generation

Since the next generation of bicycles may not fully replace the old models, at least not in the first few years, a successful formula might be to develop the product as a complementary service. The product could be a 'first-class' variant to the default service, offering a great number of benefits at slightly increased subscription fees. Should the product not catch on right away, then the community could of course receive free trial periods to become familiar with the new bicycle and the benefits it brings, stimulating climb in the adoption curve. The product should be a benchmark for a positive future image of clean, durable transport. The transition into nextgen bicycles should be made as comfortable as possible for the user, exploring the benefits of the new system with little adaptation compared to the old models. The service should evolve according to the lifestyle of the user, until it actively, harmoniously extends this lifestyle. Users should feel as if the service runs for them, personally.

01.

71 A Premium Product

A Beautiful Product

Emotional factors should be taken into account when shaping a product that is so prominently in the public eye. The bicycle's shape should trigger an emotional response in the users. The service's general image should reflect the idea of future positive thinking.

Healthy Public Transit

A next generation bike must learn from previous experience to improve on ergonomics, to reduce mechanical shortcomings and defects, and make transport via bike-share a less time-consuming operation in general.

International Compatibility

A large scale, densely-meshed network that offers pedelecs also leads to great opportunities for cities with steep terrain, especially the crowded city centres of the southern European nations. A large scale network that provides users with electric bicycles could lead to a steep climb in market share. Combined with the ability to cover longer distances, the pedelecs will be a viable option for small groups of tourists on a city trip, maneuvering through the traffic congested streets with great comfort.

02.

03.

04.

7.2. A Positive Future Image

Faster And Further

Through the implementation of the electric bicycle, users will be able to cover longer distances, allowing for expansion to suburban areas, encouraging the use of the bicycles beyond the city centre. The nextgen bicycles should be comfortable, and well-suited to cover longer distances.

Power Efficient

A driver to this project is efficient energy consumption. This can be achieved through the use of solar cells as a main power source, leaving the use of net current as a source of auxiliary power. Another possibility would be that of sleep mode stations, with bicycle docks that shut down entirely when there is no bicycle stored.

A Better City

The service should actively contribute in beautifying the city, as well as on a passively improve the city's mobility channels, through factors such as data acquisition for infrastructure improvement fit for durable mobility solutions.

7.3. An Easy Transition

Easy Charging Experience

A fourth generation system, offering the use of electric bicycles, cannot expect users to manually insert the plug when docking their bikes. Charging must be an automated consequence when returning an electric bicycle

ATrusted Service

Users should experience a seemless transition between the regular bicycles and the nextgen bikes. This is expressed through the user experience when obtaining or storing a bicycle. An important factor in the transition is pertaining the Smartbike/Velo-Antwerpen-brand. The nextgen bikes should represent the unique style of the Clear Channel bikes. The stations should also reflect the current brand. Ideally, the supporting infrastructure for the nextgen bikes should 'blend' with the current, regular stations, with slight distinctive features that make the nextgen service recognizeable from the current generation, while keeping the brand ideals intact.

7.4. A Cycling Lifestyle

An Adaptive Service

The system should be responsive to the fluctuation in users demand, at any point of the day. Station locations and capacity should be constantly adjusted to accurately meet this demand.

Reliable At Any Time Of Day

When a user approaches a station with the intention of hiring a bicycle, said bicycle should always be waiting. Reliability is one of the core drivers of a fourth generation system.

Digital Enhancement

A next generation bicycle requires a perfect synergy with digital media to enhance riding comfort. Digital applications must create a web between the user and the product, stretching beyond positioning, truely simplifying the lifestyle of the user even beyond the bike-share service.

Regulation efficiency

Regulation should be faster, costefficient, and even more responsive to current user demand and fluctuation thereof during the day. The comfort of the regulation crews should also be taken into account.

8. Product Constraints

The following pages contain a first set of constraints, based on the information available at the time, that are to be regarded pending the further stages of the design process. Some are due to minor changes as they are proven either obsolete or impractical.

8.1. System (Global)

- The average life-span of the bicycles should be \leq 10 years.
- The average life-span of the stations should be <15 years.
- The cost of yearly membership should not exceed the regular membership by more than 30% (48 Euros).
- The nextgen bicycles are able to run as a complementary product alongside the regular sharing service.
- The network should feature at least 1000 active bicycles upon startup, in order to properly saturate the city mesh structure.
- The network should feature at least 2000 station docks upon startup, to accommodate storage for active bicycles.
- The nextgen bikes must reflect the branding of the current service, but they should also induce an emotional response among users. The form factor should be attractive and appealing for use as a means of green transport.
- The service design must reflect the image of a future positive mobility infrastructure
- \bullet The service must draw ${>}20\%$ of total energy consumption from the use of solar cells.

8.2. The Bicycle

- The bicycles should have a cargo space that holds volumes defined by Ryan Air as standard hand luggage constraints:
- up to 200 mm in thickness
- up to 400 mm in height
- \bullet up to 550 mm in width
- \bullet The bicycles should have a cargo space that holds a luggage mass of up to 13,3kg (10 kg rule with a 30% safety factor)
- Bicycle cargo space must prohibit use as a a carrier for small children.
- \bullet The bicycle's saddle adjustment should take up ${\leq}3$ seconds.
- The bicycle's inward steering handle angle should be approximately 15 degrees, resulting in ergonomic arm tilt and minimized wrist strain.
- The bicycle's downward steering handle angle should be about 15 degrees, resulting in ergonomic wrist torque.
- The bicycles' handle width should be approximately 400mm (Ergotec, 2013).
- \bullet The mass of a single bicycle should be <25kg for the ergonomic comfort of users, and regulation crew.
- Bicycles include an extra locking feature for short stops while riding
- Every 5 minutes while an active bicycle is locked anywhere other than an available station dock, the user will receive a smartphone message as a reminder of used free-ride time.
- The lock can be activated using but a smartphone or ordinary mobile phone.
- Bicycle lock should be able to close within 10 seconds using a smartphone, or 20 seconds using alternative option.
- Bicycle lock should be able to open within 10 seconds using a smartphone, or 20 seconds using alternative option.

8.3. Dynamic Stations

- Stations do not require excavation upon implantation.
- Stations can be assigned to other locations with no excavation or trenching required.
- Stations are able to shift from stationary mode into a mobile state in a time span of ≤ 1 minute.
- Stations are compatible for charging electric bicycles continuously 24 hours per day.
- The user should not lift any part of the bicycle off the ground to either withdraw or return a bicycle.
- The user should not scale ramps with incline over 35 degrees to reach the bicycle lockers.
- The user should not scale curbs of over 200 mm in height to reach the bicycle dock.
- The new station's occupied surface area should not exceed the dimensions of a current station with equal bicycle capacity.
- \bullet The stations should be clearly visible on a dark, unlit night situation (0,0001 lux) and in the brightest of day (25000 lux) from 50 meters away.
- The stations should be visible over standard traffic height (1.700 mm).
- Confirming a safe bicycle return cannot delay the user for longer than 3 seconds.
- The station's location may not be closed down for use during the regulation process unless all of the present bicycles are taken onto the provision route.
- Regulators should not lift any part of the bicycle off the ground during standard regulation process (this does not include the case of defected bicycles).
- \bullet Bicycle provision should take <90 seconds (down from 300 seconds on average in current conditions).
- Bicycle withdrawal should take <180 seconds (down from 480 seconds on average in current conditions).
- The provision vehicle must not block active street traffic for a time span longer than a parking manoeuvre (<30 seconds) during regulation process.

8.4. Digital Service

- Bicycles will be equipped with GPS functionality, reliable location tracking up to 1 meter.
- Using the included software, users can signify defects on the current bicycle's gear shift, tires, saddle, frame, front and read mudguards, lighting, bell, transmission assembly and pedal assistance battery.
- Users are enabled to make reservations for a nextgen bicycle at a station of choice, up to one hour in advance.
- Users are able to make reservations for a nextgen bicycle at a station of choice as long as 3 or more non-reserved bicycles remain available for spontaneous use.
- Upon arrival at the station, finding your bike should be possible within 10 seconds.
- When making a reservation at a chosen station, smartphone applications and internet services will always display nearby full stations (push stations).
- GPS display will always show pull stations with 2 or less available bicycles within a 600m radius of the user's location, users will be incentivised to drop off bicycles at these pull stations.
- Making a reservation at an available push-station will grant the user an amount of time credit upon undocking the appointed bicycle.
- If the user runs through all available free-ride time and possible time credit, he can still prevent paying fees by returning the active bicycle to an available pull-station (if the overdue time was less than, or equal to the time credit earned at respective pull station).
- Abusing the 'reservations' feature in any way will result in users losing their stored or pending time credit.
- Abusing the 'report defects' feature in any way will result in users losing their stored or pending time credit.
- Repeated abuse of digital software may also result in real-money user fees.

9. Estimated Financials

Any of the numbers presented below, related to expenses for the nextgen product, are based on estimation and will likely differ from the cost structure of the final product. It should be interpreted as a sketched frame of reference, portraying the possibilities for financial benefit that the new concept can introduce to the bike sharing infrastructure in Antwerp.

Estimation Approach

The strategy directing the cost estimation for the implementation of this nextgen system is that of slow replacement of the current system. The system replaces the current system step by step until it reaches full saturation of the current market, fully replacing the present system. For the purpose of this costing model, this particular strategy was chosen, as opposed to expanding the system with nextgen bicycles and running both generations alongside each other on a larger territorial scale. Estimation based on a replacement strategy allowed for the financial plan for the third generation Smartbike programme to be used as a reference document, and also creates a simulation of what costs might look like if the system was implemented anew, in a city that does not yet have a bike sharing service.

Data Acquisition

The information, based on which the estimated financials for the nextgen system were calculated, is part-result of numerous contacts with Clear Channel Belgium. The original Velo-Antwerpen financial plan for overall costs was provided by GAPA Belgium. To some inquired data, no access was granted, including the individual cost per bicycle and per station, and repair costs for bicycle components. The initial development cost for the nextgen bikes and stations was estimated by an expert for 4IS/BlueCorner. These financial estimates are based exclusively on the data acquired from the financial plan of Velo-Antwerpen, and was therefore estimated only for implementation in the Velo-Antwerpen Programme. Possible implementation in other cities was not taken into account for this calculation.

Production Cost

The production cost for one station module was estimated at 2.000 Euros, the cost of an industrial mid-range AGV. If we presume that one module can hold at least 6 bicycles, then a station will consist out of 3 modules on average. If we measure up the final saturation of nextgen stations with that of the present generation: 150, the total number of modules required is 450. The purchase of station modules will evidently be split over multiple purchases, with the first being the largest (Roughly 200 modules to satisfy the initial demand) If 5 regulator vehicles are responsible for the regulation of these module (the current number of vehicles) with each vehicle costing 200.000 Euros (Estimated value based on the cost of a quality electrical AGV). This makes for a total investment of roughly 1.900.000 Euros.

The bicycle's production cost was estimated at 700 Euros (Production cost of a mid-quality pedellec bicycle). A total of 1.800 bicycles will be produced for Antwerp, to match with the current saturation. Investment cost for the bicycles subsequently figures 1.260.000 Euros. As with the stations the investment for the bicycles may be split over multiple years to more gradually saturate the entire city.

If we add to this number the development costs of 300.000 Euros and certain investments for molds and storage warehouse: 200.000

The total initial investment then figures at 3.660.000 Euros.

If the fully saturated market is the same as it is now with the current generation bicycles, than in three years time the full userbase within the Antwerp city centre will be saturated, with 30.000 average annual usership purchases each year, and an additional 180.000 day- or week-pass purchases every year.

Year-Pass Estimated Cost

An estimated year-pass cost can be calculated. This calculation is a simplified model to simulate the payback on the initial investment, not regarding partnership income or government funding. It merely shapes an image of profitable return on investment upon full saturation of a network the size of Antwerp. It is presumed that the price setting for day-passes and week-passes is done according to the same ratio as with the current Clear Channel bicycles: respectively 1/4th and 1/10th. With 30.000 year-passes sold, and 180.000 being the number of day-and week-passes sold, this presents the formula: 3.660.000 - 180.000(1/4*x+1/10*x)= 30.000*x with x being the average price of a year-pass. Simple math results in x figuring at 42.58 Euros, thus, 42,58 being the average cost for one year pass. It is likely that the price setting of the nextgen year-passes will be the same as with the regular Clear Channel year-passes, starting at a low number, then mounting up to a higher number as the market is saturated. The same strategy could be continued for the nextgen bicycles, starting the price at the same level as regular models, then slowly ramping up about 50 Euros as a maximum.

Clear Channel Operational Expenses

Needless to say, it must be taken into account that the operational costs (OPEX) will be reduced significantly due to implementation of disposal EV'S, and possible cutbacks in the number of regulator crews required for efficient regulation. As the regulation takes up two thirds of the employee force, and will for the most part become obsolete, the employee costs are estimated to be half that of the current expenses. The number may vary: half of the regulation staff in the case of modular regulation, to the full regulation staff in the case of autonomous regulation, displayed in Figure 19. Operational costs for the EV's are dwarfed compared to those of the standard vehicles accounting fuel cost. The yearly expenses would sink to about 6.000 Euros (Based on those of a quality Electric Vehicle)in maintenance costs per vehicle, giving the yearly total 30.000 Euros operational expenses for 5 vehicles (not counting possible defect repairs). The desired concept carries great potential for reducing

operatinal expenses. This result could be enhanced even further by creating more durable bicycles to reduce bicycle maintenance cost. Currently, every bicycle is brought in for repair 5 to 6 times each year. The same number of repairs is estimated for nextgen bikes. 1.800 regular bicycles and 150 stations make up for 573.616 euros of maintenance each year. Possibilities for this measure will be explored further in the system design phase of the project.

OPERATIONAL EXPENSES	CURRENT PRODUCT	NEW GENERATION
EMPLOYEES	1.388.313	694.156
ELEKTRICITY	27.381	27.381
BIKE/STATION MAINTENANCE	573.616	573.616
VEHICLES	162.240	30.000
USER CARDS	4.382	4.382
CALL CENTRE	85.939	85.939
BANKING FEES	81.388	81.388
FRONT OFFICE	102.199	102.199
IT	37.457	37.457
MARKETING	75.000	75.000
TRAINING	24.970	24.970
PROJECT MANAGEMENT	313.000	313.000
THIRD PARTY INSURANCE	5.500	5.500
CONTINGENCY	277.283	277.283
TOTAL OPERATIONAL EXPENSES	3.220.989	2.332.271

Figure 19: Possible difference in the service's yearly operational expenses by optimizing regulation

10. Conclusion: New Product Planning

Within the time span of this research the world of bike sharing systems was explored for opportunities that could invoke innovation to a true fourth generation network. This page contains a summary of general findings in the course of this research.

Firstly, the concept of bike sharing was explored in its context, relevance and potential areas where innovation is due. The history of bike sharing was analysed for critical factors that led to the successes and failures of past generations. Through this analysis, the concept of bike sharing could be observed at its roots, at its essence. A general mapping was made, consisting of prominent networks currently in existence. Four of those networks were discussed further because of specific characteristic features of relevance to the project. These explorations provided a number of domains for further research in the second part of the analysis, which discussed the feasibility of technological advances within these domains, to improve on the functionality of bike sharing systems. The third segment shed light on the sociologic context of the design project, and how to improve on the current bike sharing experience both from user perspective, and that of third party members. Furthermore a thorough analysis into the workings of Clear Channel's Velo programme was conducted. As the project is slowly taking shape within the context of Velo, the bicycles were tested and observed for flaws. The service workflow was studied in a field research alongside the regulation teams to establish an overview of the complete system's workings and factors of influence to the design of a fourth generation product. The cumulated research led up to an early concept for an electric bicycle with a dynamic, flexible infrastructure. For this a product architecture was devised, with the necessary product specifications, as well as an early estimation of price setting.



system design

The system design phase presents a closer look at the bike sharing product candidate, defined in the previous section. Firstly, the topmost level of design, the macro level, being the system logistics themselves, is discussed. Secondly the multiple facets of the design are looked into. These are now categorized into three major touch points: the centre product, the bicycle; infrastructure, dynamic drives, and digital supportive platform for mobile devices.



11. Defining the next generation

Stemming directly from the New Product Planning phase, this first chapter summarizes the factors defined as key components to the product candidate, in the order they will be discussed during the continuation of this essay.

Three Touch Points

The system design phase is divided according to the three carrier components defined in the first part of the project. Firstly, there is the bicycle, the centre product of the network. Secondly comes the flexible station, which can adapt its size according to user demand fluctuation. Thirdly there is the virtual system, a digital platform meant to enhance user experience, gamify the bike ride, and implement new functions such as health ad cardio, positioning, and user driven disposal.

A New Bicycle

The first aspect of the system design is that of the bicycle. The design will be rather straight forward, as many of the features were defined in the planning phase of the project. The bicycle design will focus mainly on aesthetic problems and styling, as well as keeping the Clear Channel branding intact.

A Better Station

The station is a more abstract part of the project, and will receive a strong focus in the system design phase. As the infrastructure will have to be a close compromise between price setting, ease of use, and compact placing, an efficient system design will be of critical importance.

Digital Enhancement

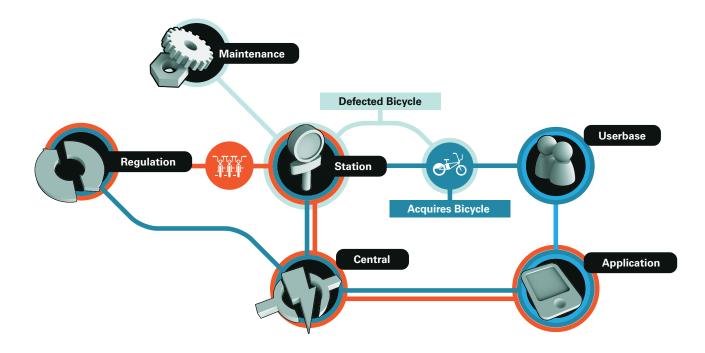
The digital platform, the application in which the service will be embedded will play a pivotal role for the user experience of the product. In the course of the system design phase will be decided which features to include in the platform, and how these features will be incorporated into the user interface.

11.1. Defining A Network: The Main Actors

A bike sharing network is succesful through good interaction between various forces. These actors, the clockwork of the system, as it were, are defined in the scheme below (Figure 20). Firstly there is the user, who comes into contact with, on the one hand, the system's infrastructure: the station, and the digital user platform on his/her smartphone. The user can acquire a bicycle at a station of his choice. The station connects to a central server which updates the station's status on both the user's smartphone application, and the regulator positioning device. Should a station module run out of bicycles, or get dangerously close to running out, the regulator team is assigned to perform either a refill, to add extra filled up modules, or to take out the empty module, possibly replacing it later with a full one. If the user notices that a bicycle is defected, he can return it to a nearby station, and signify the maintenance unit.

This feature will be enhanced through the digital application included in this concept. It is not excluded that the station hubs themselves will also feature a defect report function. The station modules are interchangeable, that includes, if regulation requires a certain station to feature additional bike storage space or a greater availability of bicycles, that any set of modules can be swapped and moved from one location to another to more accurately meet user demand. Station modules are connected to a fixed stationary outlet that will serve as power supply, and may also incorporate the function of the access kiosk. As an alternative to registration at this kiosk, users can use their smartphones to access the bicycles. A statistics log is kept on the demand the succes of each module per given location. The location setting of the modules is determined by positioning devices located within each module. It is of course advised to keep at least one module stationed

Figure 20: Different actors in the bike sharing system, and their relevance in different interactions.



Among the benefits of a stationary base hub, is the fact that any bigger electronic components can be hidden inside of the kiosk. The solution also makes for cheap stations, as any smart components may be housed inside of the access kiosk. Only one user interface/display is required. Full-access modules are considered as an alternative, with integrated access kiosk modules (one per module, or even an access interface for each individual bicycle) The benefit of a fully equipped module, is that it requires less planning ahead in terms of power supply: the number of bicycles docked is always sure to have a stable charge rate. It furthermore grants more user comfort through reduced walking distance to and from the access kiosk, which will in this case be placed over a maximum distance of 6 meters. Although these solutions would provide a more integrated, and more mobile feel to the dynamic stations, there are a number of relevant issues to be considered. For starters each of the modules would require power supply either through battery support or through a separate hub such as public power outlet. Other requirements include displays and keyboard interfaces for each module, causing a dramatical increase of total cost for a station. Every module would have to be a smart module, with integrated positioning system and a smart coupler that could recognize other modules. Further consideration of possible station options is documented in the next chapter.

12. A Dynamic Station

The dynamic station, which can be coupled and removed in a modular fashion to add bicycle capacity on locations where it is needed, at any given time, is a whole new concept. The main feature of the station, aside from the fact that requires no excavation, is that it can be transported with bicycles on it, and this proved to be the major challenge for system design, and all subsequent subsystems are based of this general structure.

12.1. Modular Station

Complicated Puzzle

Generating solutions for the modular structure of the dynamic station was a tedious puzzle. Whenever a new possible solution surfaced, a load of limitations and problems quickly nihilised its potential. The first two alternatives considered were fully mobile in the way that they could be moved without the need for a lifting device. This eventually proved impractical, research progressed into structures that were efficient as to their lifting mechanism, and transportation methods.

Wagon Model

A wagon-style module was a logical solution for the problem. However, then chassis needed for these modules would drive up the expenses per module. The wagons would also be way less convenient for complex manoeuvres (mostly on account of their length) in the more narrow city corridors.

AGVTransport

Autonomous modules would of course raise the bar for public transport everywhere. Smart, guided wagons with small four-directional crab steering that could easily find their way through the cityscape. A smart module that would require no regulation crue whatsoever would decrease floating costs significantly. Sadly, autonomous traffic solutions are not a point were they would provide a viable design solution. The smart modules would be a popular target to vandalism and would frequently require assistance when stuck in unorthodox traffic situations.

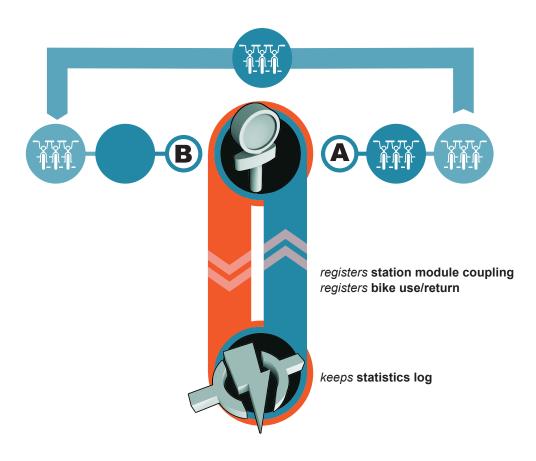


Figure 21 : Modular Station Principle

12.2. The Secret Design Drivers

As the process of examining, generating ideas, validating said ideas, and finally aborting the ideas continuously iterated upon itself, it became clear that certain factors of influence were steering the evaluation of the concepts. These factors were not mentioned in the drivers section of the research, and only started to surface when looking at the invidual problem of modularity. These critical factors were named the Secret Design Drivers.

Compact Storage

The bicycles should take up as little space as possible, while still remaining accessible to users. Preferably the dimensions of the new stations should not exceed those of the old models (relative to the stored number of bicycles).

Modular Structure

The stations should be flexible in their size and capacity. An important note is the need for double-sided stations, as well as single-sided models for a bigger array of placement options.

Efficient Transport

Driving the modules around (with bicycles included) should make for efficient logistics. The transport vehicles should move the bicycles at a rate that at least matches that of todays regulation.

Economic Solution

The modules will be great in number, and should therefore be as cost-efficient as possible. Hi-tech complicated structures will not do. Furthermore the number of smart components including digital screens and controllers should be reduced as much as possible, as well as the cost for power supply of the stations. This is intertwined with the station installation procedure. Ideally power would be supplied by a single power outlet.

Vehicle Compatibility

As the regulation vehicle would not be revised within the scope of this project, the station module should have a certain compatibility with existing transport vehicles. I would be most unprofessional to leave the regulation vehicle options a complete black box solution.

Little To No Installation Cost

As determined in the research phase of the project, the new station should minimise the cost for implantation. Most bike sharing stations to this day require excavation and trenching. These tedious installation procedures are a serious cash sink to most third generation systems. A fourth generation station concept requires quick, and more efficient installation properties.

Manoeuvrable

The stations can be placed anywhere near the city's mobility infrastructure. This means busy spatial avenues, but also tight corridors and pathways. Regulation should be efficient in all possible situations. This includes placement under difficult angles, where the stations may need to be placed directly next to the regulation vehicle. Another scenario could be a spot that is difficult to reach, where the vehicle has to bridge a certain distance when placing the modules. It is not excluded that multiple vehicle models are responsible for the regulation of station capacity.

Mechanical Simplicity

A successful design is as simple as can be. Mechanical simplicity reduces the component cost for almost any product. It also reduces the chance for mechanical error and component failure. For these reasons the final driver of influence in the evaluation of generated ideas is that of mechanical simplicity.

12.4. Intermodal Modules

Designing A Universal Station

Designing a regulator vehicle was never a part of the project scope. It was however vital to the viability of the concept that the station should realistically be compatible with an affordable vehicle. This could be a flatbed truck with a mounted crane, a simple towing truck, or even a car by means of making the stations into attachable wagons. Though multiple potential solutions surfaced, the set design drivers were never met on any solution, and mainly the compatibility with a realistic regulator vehicle was the cause of an early termination for numerous ideas. Eventually one particular concept surfaced from the rejects. This idea, however simple, fit all the set requirements. The stations would be dimensioned according to the size of standardised freight containers. A fixed module equipped with an access kiosk will determine the placement of the station. In this central module are hidden most of the power supply components, including the outlets, converters, and the couplers for power supply to connecting modules.

Smartphone Access

Users will generally make use of the smart-card/access kiosk combo to pick up a bicycle for reservation. In the next generation system, however, there's also the possibility to check in via smartphone application. The user may simply approach a station with the application activated and he will automatically be prompted to obtain a bike. The user may then accept or decline to pick up a bicycle. If the user has a pending reservation for the station, and arrives at the preset time, his bicycle will automatically be appointed to him.

Module Power Supply

When it comes station power supply, there are a few possibilities to consider. Firstly, there's the option for direct power supply from a battery on each separate module. These batteries could be charged at the main office, or on the spot through the use of solar cells. Every so often they can then be replaced by the regulation crew when nearing depletion. A second model could use a single power supply, using either batteries or net current. One module is connected to this power supply, and transmits the current to the other modules through various couplers.

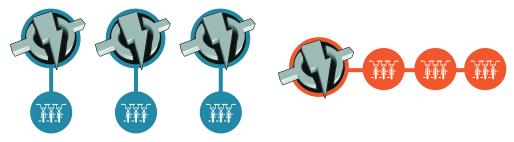
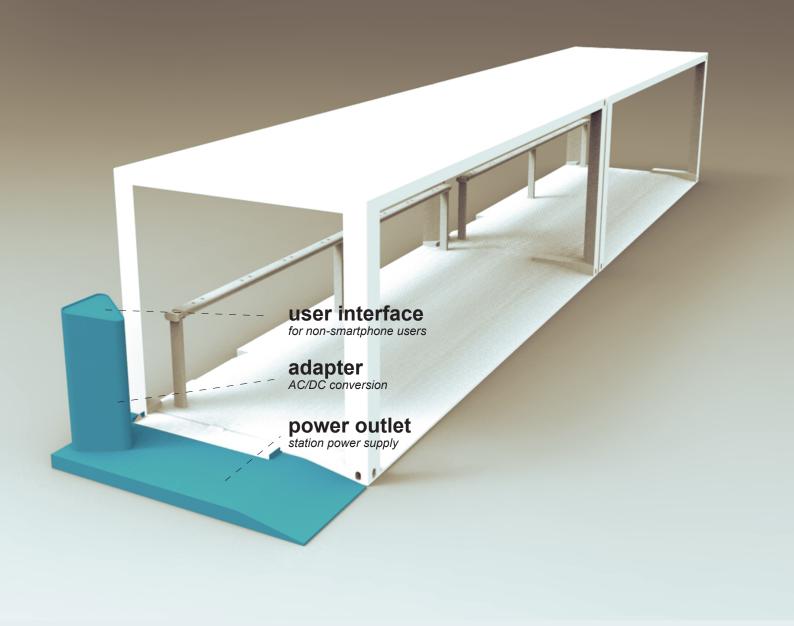
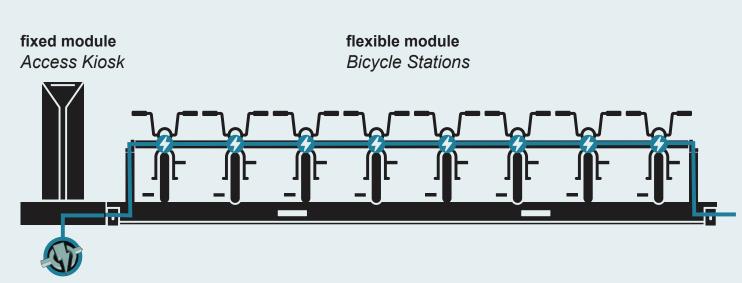


Figure 22: Battery powered modules versus central power supply





12.5. Module Connectors

The dynamic bike sharing station has dimensions based on those of freight shipping containers. This choice was mainly determined by the increased compatibility with a number of conventional transport vehicles. Because of these standardised dimensions, it seemed rather logical to first conduct a search into existing connector mechanisms for different containers. Sadly, solutions turned out to be rare. A latching device was found, allowing two containers to snap together without the need for further user interaction. As patents containing fast single-action connector devices seem almost non-existent, other fixtures were explored, mainly latching devices for containers on vehicles. The search produced a few relevant and inspiring

documents, but no integrated covered power supply or any of the sort, the hoped result. Thus the, rather fruitless patent search was abandoned.. Eventually a simple, yet effective mechanism was devised. The chosen solution includes a simple industrial plug connector, cheap and flexible, with a certain tolerance in terms of placement in linking the modules. This piece of cabling is shielded from users thanks to a simple sheet metal cover which initially would be fixed by means of two anti-vandalism bolts. This sheet metal part fulfills both the function of a walking surface, a bridge that connects the base plates of two modules into each other, as well as the function of a ramp, whenever a module is on its own.

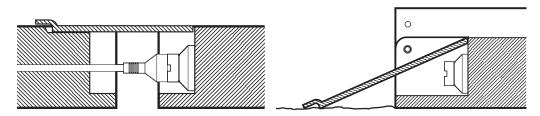


Figure 23: The sheetmetal coverplate principle

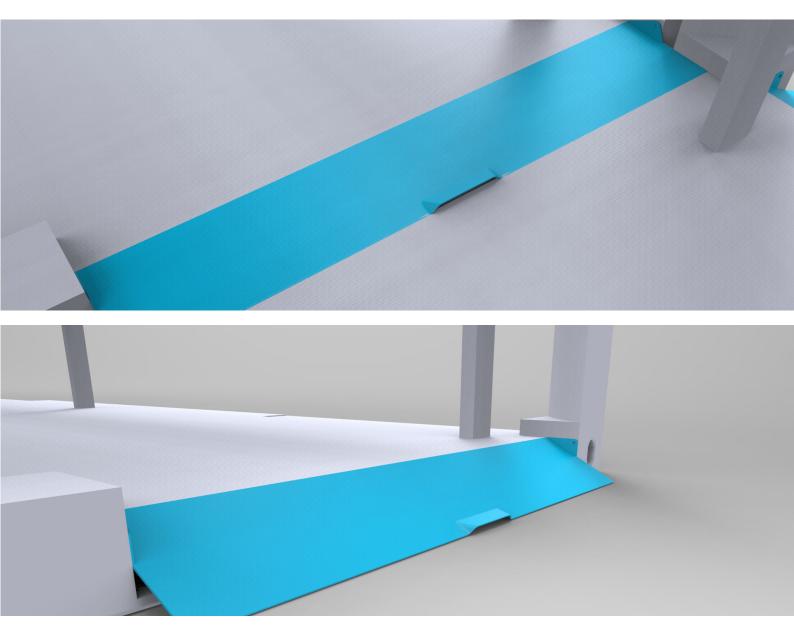


Figure 24 : Schematic representation of the coverplate workings

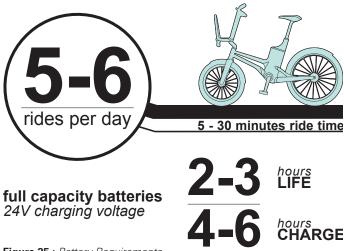


Figure 25: Battery Requirements

12.6. Battery Life And Bicycle Allotment

Generally speaking, the individual bicycles are used five to six times each day. (Rondeaux, 2013) A single ride will have to be too long a distance to walk, but can not stretch beyond the 30 minute milestone. Rides longer than the 30 minute mark are charged with an extra fee, and even though time credit may stretch the ride time a little longer, this will not be of significant influence to the average ride-time. The average time is estimated at 30 minutes. This is a gross overestimate, but safety margins have to be taken into account as bicycles at popular stations will see more use than others. Commuters who take bicycles to a commercial zone over great distance may also require longer rides on a regular basis. Therefore the lifecycle of a battery, which should see the bicycle through the day without the need for charging, should be at least 2 to 3 hours. The charge cycle back from zero percent to full charge will then generally be 4 to 6 hours, which can easily be achieved during the night hours, when the bicycles are barely used. Charging is therefore not an issue, as the bicycles will always reach full battery capacity before the rush hour starts.

The lifecycle of the battery, and its dimensions, are the only critical factors when selecting a battery model. When considering the distribution of bicycles on a single station, a few scenarios can be taken into consideration. As a first model, the station would simply assign the bicycle with the most battery life to the first user that comes by. Then the bicycle with the second most battery life, and so on. This simple model would however implicate that, for example, some users that require a bicycle for a short distance would be given a bicycle with a full battery, whereas users that need a longer transport may be given a lower battery as a consequence. This could be perceived as inefficient use of battery life. However - in the case of the short ride - at the next station this example bicycle will once again be handed out fairly swiftly, gradually levelling the battery ower with other bicycles in use. Whereas the bicycle that travels over longer distance will be kept at the next station for a long time before it's reassigned to users. In any case, as mentioned in the previous paragraph: the bicycles will be equipped with the necessary battery life to live through almost any day schedule.

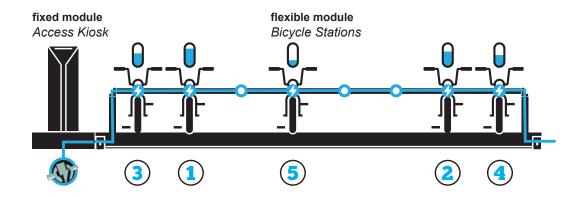


Figure 26: Bicycle allotment according to battery life

An alternative model could include the option to select a destination location for your bicycle when placing a reservation. The reservation model allows you to keep a bicycle out of regulation for a short amount of time. The same could be done for station sockets at the destination, keeping a free locker space for a bicycle to be docked. This would however implicate that one reservation would make not one, but two station lockers inoperable, one with a bicycle docked at the acquiring station, and one empty locker at the destination. This would lead up to double the frustration by users trying to dock their bicycle at the destination location. Furthermore it would impede on the user's freedom to choose which station to dock at while riding, a feature which lends bike sharing its most prominent aspect: its simple and flexible nature. As a result, this model was not implemented, and only the first, simple model will be used for bicycle distribution by the station controller.

12.3. The Bicycle Couplers

The bicycle locking system was quite the challenge, as a centre requirement was to design a locker compatible with both the new electric bicycle, and the old non-electric model. Furthermore the charger system should be as economic as can be, using old parts if at all possible. A third factor of relevance was user friendliness, whereas the system would have to be as simple and intuitive in use as the old one. Ergonomics made up another requirement: the bicycles should not be lifted above shoulder height for placement, even though this would make for compact storage. Then there was the issue of durability. The lockers would have to stand heavy use, the chargers would need to be resistant against perpetuous harsh weather, and last but not least, the lockers would have to withstand years of city nightlife, vandalism, and attempts to steal the bicycles. A robust lockand charger mechanism was thus required. For the design, therefore, the components of the original locking system were retained where possible, creating both an cost-efficient solution for the Clear Channel program, as well as keeping the original brand image, the vertical anchors and the round locker sockets, intact.

Considering inductive versus conductive charging

A first design explored an inductive charger system. While induction seems like the most promising method of power transmission for outdoor applications, there are a few factors that need be taken into account when considering such system. The most prominent factor against the inductive charging method is the aspect of safety. The magnetic flux, at a current as large as to charge a bicycle, causes rather significant radiation around the charger device, forming a significant health risk to users with a health condition or a prothesis such as a pacemaker. There was also the increased cost to consider, as well as the loss of power efficiency. Because of these considerations, it was eventually opted to use conductive charging as the chosen method.



Figure 27: Quickdesigns regarding power transmission from the locker on to the bicycle

Conductive Method: Jack Pin

A first solution that made use of a conductive system worked using a powered pin that fit into a recess in the bicycle's anchor points. An insulated copperwire then transmitted power from this recess through the frame onto the bicycle's battery. However logical, the solution brought various components fragile to abuse and vandalism, and offered little durability against bad weather.

Conductive Method: Powered Locker Axis

A second exploration made use of the locker shaft for the current flow. Through this axis, the flow was escorted to the anchor, and then through copper wire to the battery, much as the first option. What makes this solution feasible, however, is the fact that the shaft offers as a first, a much more robust and durable solution. Secondly, it also makes for a strong friction against the anchor points, so that build-up of electric resistance (as a result of prolonged outdoor use) is prevented. Both anchors and conductor axis are, as is to say, polished anew with every bicycle docked.

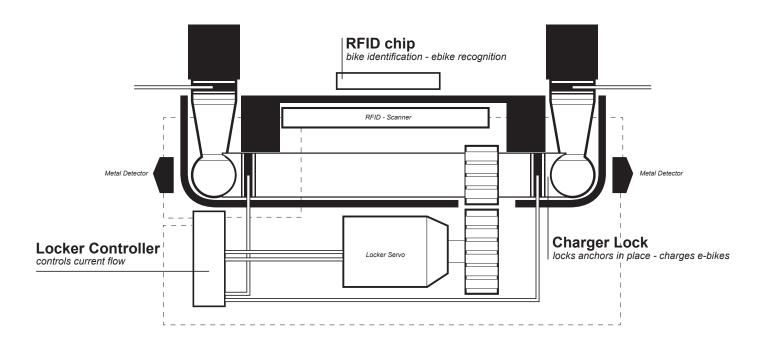


Figure 28 : Schematic representation of the locker assembly

13. An E-bike For Public Purposes

The bicycle was an issue which mainly time would be spent in the product design phase. However, a few critical components and subsystems had to be validated because of differences as opposed the conventional bicycle.

13.1. Decomposing The Electric Bicycle

The standard electric bicycle consists of several key components that should be included in the new design for the ebike destined for public use . First, there is the engine , for which a pedal -assistance model was chosen earlier in the project. The pedal assistance electric motor provides power automatically , based on the torque to the pedal-axis , supplied by the user. This engine is always active, and thus requires no control button or console on the steering handle of the bike. Nevertheless it rarely requires full capacity input power. The appropriate battery component should also be present. This part, although present-day private models are already quite subtle, should be validated

on certain critical factors other than its dimensions for feasibility. It must be particularly resistant to harsh weather conditions, and fit for use in the public service, in which the bicycles have a nearly continuous circulation. This means that the lifespan of a single chargecycle is a very important factor, more so than is the case with a conventional ebike . Unlike a bicycle intended for private use, the frame of the bicycle must furthermore be dimensioned according to the physical qualities of the 95th percentile . This means that a large adjustability of the seat is required, as well as a low entry height , and thus a low top tube.



Figure 29: 2013 C onventional ebike study

13.2. Bicycle Structural Components

Because the subject of this thesis project is the design and development of a bikeshare bicycle, and not that of a regular electric bicycle, several factors should be taken into account whilst designing this particular bike. Factors that would've been entirely neglectable for a conventional e-bike. Firstly there is the need for a universal bicycle, this implicates that the top tube must be below pedalling height for easy mounting and dismounting. As a second primary requirement there must be adequate space for luggage on the bicycles. Every bicycle should fit medium sized luggage sizes according to the ryanair standard of 200x200x55mm. Saddle height must evidently be fully adjustable. Sturdyness is another important issue, tangible components such as luggage racks and mudguards cannot be of the delicate nature as they are on regular bicycles. They'll have to be durable, and fit for harsh conditions, both from weather and usage. Battery and motor unit will have to be as sturdy, and safely hidden from sight to prevent vandalism actions. Cables, especially those of the charger assembly, will have to be hidden from reach, and even from sight wherever possible to prevent vandalism.

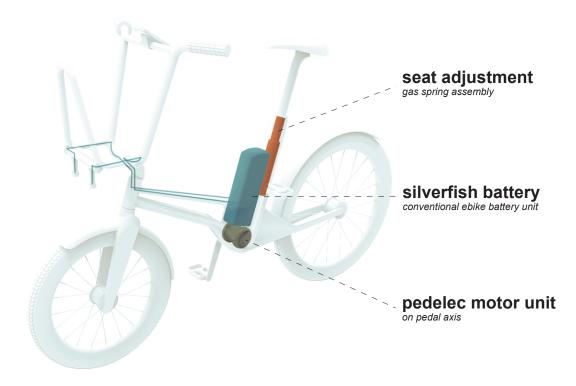


Figure 30: Schematic representation of Smartbike inner architecture

13.3. The Motor Assembly

Choice of Battery Model

Pedelec bicycle motor units consist of three major components. The first is a battery power supply, which in this case has to be locked away in a secure manner as it's vulnerable subject to theft. To avert the need for architectural changes in the bicycle's frame and alignment of primary functions, the battery was to be mounted in the centre shaft of the bicycle, above the pedal axis. The battery model would have to be as slim as possible: a silver fish variant was chosen. The Silver Fish model is a conventional lengthy vertical battery pack specially made for electric bicycle models. The other two major factors, being the pedal torque sensor and motor unit, took a little more consideration.

Motor Option: Rear Wheel Hub

Numerous conventional e-bike models are in existence that use front wheel traction. This motor variant however is the cause of many a displeased user. A front wheel motor unit causes discomfort while riding, as the bicycle feels as if it's being pulled forward at the steering wheel. This model was not considered for use. The first model taken into consideration is that of a rear wheel motor unit. The drive assembly includes a motor unit in the rear wheel hub, and a separate sensor module, replacing the pedal axis. As with all pedelecs, the sensor module measures torque exerted on the pedals by the user. It transmits the information on to the motor unit, which inputs electrical assistance accordingly.

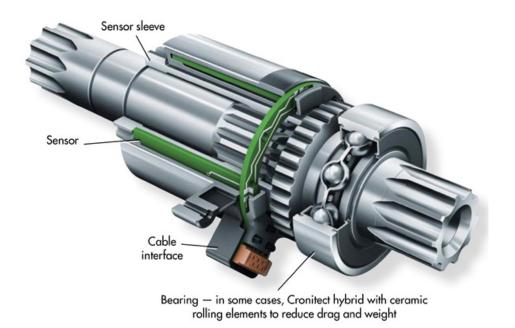


Figure 31: Pedal axis torque sensor module (Machinedesign, 2013)



Figure 32: Flykly Smart Wheel (FlyKly, 2013)

The Smart Wheel

The motor of the new public electric bikes would have to be, among other factors, an economically favorable solution. A number of options were considered. This first one is a rather startling design only a few years into production: the smart wheel. The smart wheel is an innovative bicycle product that exists only since 2013. This pedelec drive assembly fits entirely into a magnified plastic wheel hub inserted into a standardsized wheel. In this plastic casing are all vital components, including battery pack, torque sensor, and motor unit. The wheel is sold as a standalone product, implying that it can be installed onto any bicycle, simply by replacing the rear wheel with a smart wheel, a very cost-efficient solution that also keeps the charm of the original bike intact. Because there was the strong consideration for the specific use of this product as a motor, the smart wheel was deemed relevant for a study into existing patents and patent applications. As the project concerns the design of a system, a bigger picture than simple bicycle augmentation -the scope of the smart wheel market- a cooperation possible through licensing payment could prove more interesting than the development of an entirely new smart wheel. Bike sharing is no direct competitive threat to electric bicycles or the smart wheel, rather the opposite: it can be a means to create awareness about the subject. Only one patent publication was found, though thurough internet search revealed a number of product variants, these do not seem to have been protected by patent application. This particular patent has been granted, and is still on active term. At the time of this specific patent research, which first happened during the system phase of the project, the smart wheel product was strongly considered for use under licensing fee . The idea was later abandoned, and switched out for a conventional coaxial motor unit on the pedal axis, as the bicycle charging infrastructure was switched from inductive charging to conductive charging for increased economic feasibility.



Gruber Assist Kit

The gruber assist is a state of the art pedal assistance unit which mainly consists from a electrical motor unit so thin and subtle, it can be inserted into the standard saddle tube. A bevel-crown gear transmission causes the assisting torque on the pedal axis. This type of motor is very compact, and therefore very subtle. In most cases there's no need for the slightest adaptation of the bike frame, not counting the battery pack mount.

Although the Gruber assist kit presents a functional solution, and an esthetically attractive motor unit, a few important factors must be taken into account. The bicycle's saddle tube must also house the gas spring assembly, these two components would outrule each other in the assembly. There is also the high price setting to consider: one kit costs as much as 2.250 euros, as much as ten times the value of the standard coaxial motor unit.

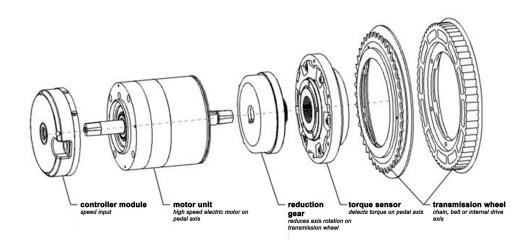


Figure 34 : Coaxial Motor Unit (Eprodigy Bikes, 2014)

Coaxial Motor Unit

Thus the final option was that of a coaxial motor unit: a convenient modular system where both the torque sensor and driving motor unit are located directly on the pedal axis. The device consists of sensor module, which sends torque information to the controller module, which then sets the motor unit to assist in a harmonious fashion to the user's force input. While this component is a standard solution, and has little innovative appeal compared to the alternatives presented in this chapter, it might just be the most practical solution, as the expensive gruber kit would eliminate the gas spring component for saddle adjustment, and the smart wheel would require additional safety measures and an external power transmission.

13.4. Considering The Smartbike Architecture

Bike Rack And Binder

On the subject of luggage, a few options were considered as an alternative to the luggage rack and binder combination, but these were soon discarded for various reasons. A basket, while seemingly the quality alternative of the standard rack, comes out as the lesser alternative for a public purpose. Michel Dallaire, designer of the Bixi programme bicycles, states that "You'll find that your bag does not fit in a basket, and they get filled with garbage. By using a rack you have more flexibility." (Citibike, 2011) Other options included the cargo bicycles discussed during New Products Planning (which would provide a good limited offer parallel product, but not in line with this project) and a

design for a confined luggage space on the frame of the bicycles, but this proved too narrow due to the fixed dimensions of the bicycle being too small. The binder was not an item included in the scope of the project. Though it is likely that other, more durable alternatives may be possible to contain luggage on the rack. They might even exist, but in all likeliness they will be more expensive. Alternatives such as clamp mechanisms or flexible plastics may seem like a healthy option, but will ultimately prove to be a waste of materials for a solution that is just as easily vandalised as a simple elastic cable. Within the scope of the project, the preference was for an inexpensive, easily replaceable component: a binder.



Figure 35 : Old quickdesign where luggage was stored in between the rider's knees

Bike Seat

The saddles are coated in a hydrophobic film for water resistance and a faster drying process. The design of the seat surface slopes in such a way that drops of water will run off the side or into the two little grooves in the saddle which guide it off the rear end of the seat. A simple gas spring is embedded within the frame. The seat assembly is characterized by an adjustment mechanism similar to that of an office chair. The user can simply flick a lever while sitting on the bike saddle, and it is lowered or raised until, respectively, his feet touch the ground or the saddle his/her rear. Standardised height markings are applied on the saddle axis as an additional reference. The user can thus already note if the saddle is at the correct height before he even gets on the bike. A small extruded ring, seemingly a cosmetic feature, right above bike seat's shaft, also further ensures that the saddle cannot rotate even under the influence of user force or bumpy roads, which is currently still a problem with the older bikes. The gas spring mechanism, which is in effect quite simple, will not be materialised during the product phase. It was developed on to system design, and will be kept at this level for the remainder of the project.

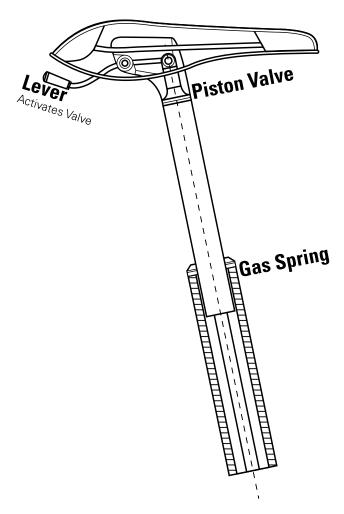
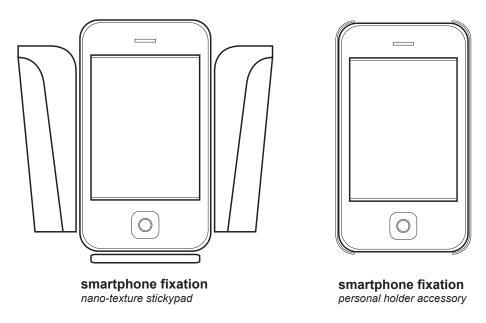


Figure 36 : Schematic representation of the saddle adjustment

Figure 37: Two possible conventional mounting principles for smartphones



13.5. Smart Device Mount

Two general device categories were researched, after eliminating some of the more delicate solutions such as sleeves, fragile enclosed containers and systems that relied on strapping in the device for fixation.

Mechanical Fixture

Under mechanical fixture are categorized all holder components that rely on only mechanical features to hold smart devices in place. A patent search, meant mostly for inspirational purposes, provided two relevant patents for this kind of fixture. The first was an application (both united states and international) for a patent that holds significant resemblence with a quickdesign that was made earlier. It involves a special device casing, which can be locked onto the actual holder using a rotary motion. A spring component holds the lock in place after the case is secured into its socket. This is the only difference, as the system described in the thesis document relies on material friction instead of a spring component to prevent the lock from opening. In short, it was the optimized version of the quickdesign sketch. For these reasons an actual collaboration with the owner of this ROKFORM patent may be considered for implementation in the Smartbike programme. Another patent which proved relevant is an application for a simple, low-tech system which uses pinching snaps to secure the device. This design, although it is described as a universal solution, has little flexibility toward size of different devices. It however provided good inspiration during the design process.

Sticky Pad Technology

Applying a film with frictional qualities was considered a possible solution for fixing fixing a smart device upon the steering handles, as the pad is very flexible toward different devices and device models. However, as the choice to avoid any strap feature to further secure the phone, the sticky pad may not be a valid option, as the phone might get shaken off on road bumps or in case the bicycle were to fall over.



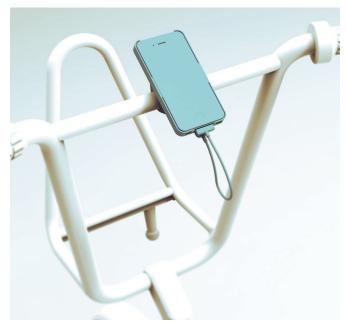


Figure 38: Schematic representation of a smartphone cover and the holder

Decisions

Eventually a fairly simple mechanism was chosen, based on the existing Quad-Lock principle. The user places a specially made smartphone cover over a locking protrusion, and thus presses into a spring loaded clamping component. By turning the phone back to its proper position, and leting go of it, the spring shoots back up, clamping the cover, and thus the device is secured put.

14. Mobile Functionality

A digital platform that actively embeds itself into the lifestyle of the user. That is the main driver guiding this segment of the project. The digital application should be provided to users via multiple mobile platforms, be it smartphones or tablets. Needless to say this application would provide a deeper experience than simple user positioning.

The digital platform was divided into three operating fields for development. The first would be that of direct influence to user lifestyle. Under this category would be the most groundbreaking additions to the mobile system, stretching beyond pure bike sharing, blending in other user experience elements that complement the cyclist lifestyle. The second category includes functions related to the product itself: the bicycles.

The two main functions defined under this category are the abaility to make reservations, as well as a defect report function for ease-of-use when defects occur. The third and last category consists of systems regarding the service. This category includes the time-credit function . Although this function will likely be found in combination with the positioning feature, it is an item worth mentioning on a separate note.

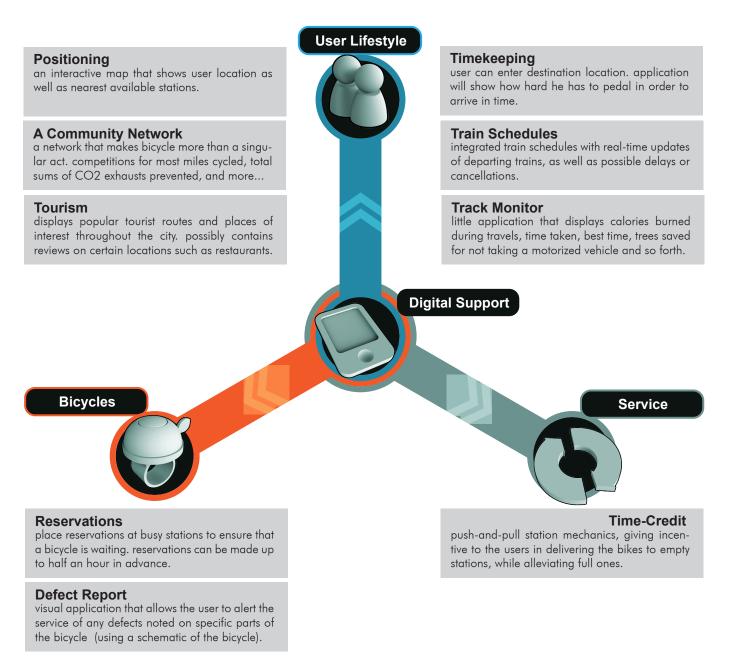


Figure 39: Brainmapping of digital platform functions

14.1. Lifestyle Branch

Positioning

A much needed feature is of course that of a fast real-time updating positioning system. This system would likely consist of a map with nearby stations, user positioning, as well as other options derived from the list of functions listed below (to be shown and hidden at the user's own desire). Positioning could operate using a kinetic GPS system in the bicycles themselves for a fast, reliable position tracking. Of course it may also be presumed that smartphone technology will only develop faster in the near future. This medium is more adaptive, and leaves more room for change. New technology such as the 4G networks that are now kicking into action would make fast position tracking almost as efficient as a mounted GPS tracker on the bicycle.

A Community

An important interactive feature that could lift bike sharing from its current state into a more engaging experience. A great benefit of cycling compared to driving is that groups of people can ride and be socially engaged at the same time. People could be actively engaged to participate in the network's experience via, inter alia, ladder standings on who is the most environmental traveler, who had the most mileage, and so on.

Tourism

The mobile application could be a great way to engage tourists, giving users the option to display various tourist attractions on the map. As a combination feature with the community feature, users might be given the option to, for example, write reviews on restaurants and hotels, which may then again be accessed by other users to read.

Timekeeping

A luxury feature by which users might input a desired destination, the service will then estimate travel time, and the speed at which the user should ride his/her bicycle to arrive at that given time. This feature is under consideration as it may cause unwanted stress while riding.

Interlinked Public Transit

Integrated train schedules displaying train departure times, with live updates, for users to see while riding. Possibly to be combined with time-keeping feature above to display at which time users will arrive at station and how fast they need to be.

Track Monitor

A track monitor could add a fun factor to the riding experience, in close relation to the community feature. The track monitor could be used to keep score of, for example, total distance travelled, time needed, fastest routes to certain locations, calories burned, trees saved, and more.

14.2. Bicycle Branch

Reservations

Reservations make up a feature of crucial importance to commuters. It introduces a new, 100% reliable way to secure a last-mile ride from their preferred transit stop to the workspace. The feature also provides the service with helpful feedback as to how station demand curve will increase over the next short span of time,

which allows for a more anticipating, thus more responsive regulation procedure.

Flexibility

One of the prime critical factors to the reservations feature is preserving the flexibility of the network. The aspect that differentiates a bike sharing network from other variants of public transit is the factor of control. The user has the choice where to ride, which route to take, where to start and stop. Introducing an element of planning, of anticipating and fixing a bicycle to a certain user at a certain time may very well destroy much of this flexibility. It is therefore required that reservations are approached with a care, so that they

introduce increased reliability, at no cost of the network flexibility.

First Model: Fixed Timespan Reservations

A first option for reservations would be the simple fixed model, whereas users can make a reservation for a bicycle and have to obtain their bicycle within said timespan. For example, while on the train a commuting user makes a reservation for a bike at the terminus. He then has 30 minutes before the reservation expires.

Second Model: Set Timespan Reservation

A second option would let users determine the time of reservation for themselves. A user could in this case decide upon which station to secure a ride, as well as the time of departure. This would then be translated into a tolerance of, say, 15 minutes in advance up to 15 minutes after said time.

121

Reserved Bicycles

If one were to make a reservation, that means a bicycle will be inactive for a set time. Unavailable for casual users, and at the same time not yet in use by the owner of the reservation, i.e. valuable ridetime is being wasted. Therefore it is critical that users pick up their ride as fast as possible once a reservation is made, or at least reduce the amount of downtime for a reserved bicycle. All of the above considerations eventually led up to the final system: Flexible Reservations.

Flexible Reservations

The user can schedule a ride up to 24 hours in advance, using the application on his/her smartphone or the service website's application. The bicycle however, is only kept at the station a half hour in advance. This means the bicycle stays active up to half an hour before the user will pick it up. A text message will be sent, notifying the user of his/her reservation. Once this half hour passes, another ten minutes of buffer time remains for the user to pick up the bicycle. When even this buffer time has passed, the bicycle becomes free for others to pick up, and the user receives a message that the reservation has expired.

Defect Report

A feature that facilitates reporting defects will definitely be of great benefit to the regulation and maintenance workers on duty. The application will display an infographic chart of the bicycle the user is currently riding (Possibly the user can first select between electric and non-electric model if both are in operation) On the schematic image, the rider can select which part of the bicycle is faulty, and even leave a comment about the particular defect if desired. The defect report is then immediately sent to the service's central server, and regulation is notified of the defect when assigned for balancing the module of the defected bike. As a result, regulation staff will easily be able to determine whether or not the defect can be repaired on the spot, using spare parts, or if it has to be sent to maintenance for a more thurough repair procedure.

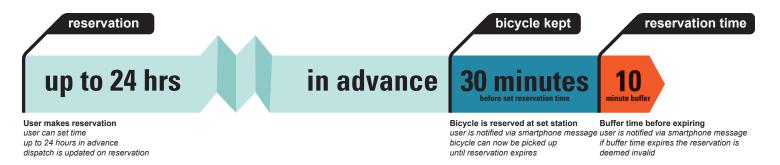


Figure 40: Flexible Reservation Mechanics

14.3. Regarding Time-Credit: To Gamify Bike Sharing

it is of course tempting to extend time credit feature beyond an incentive for push and pull balance. It could easily be a feature that defines the network as a whole, for example to make people lose time credit if they place a bicycle in a heavy push station (one that needs to lose bicycles rather than gain them). To be even more abstract: the system could be so flexible that it doesn't even need to depend on infrastructure. The bicycles could contain a GPS-tracker and a smart-lock, which means they could be left anywhere. To charge them, a handful of loading points could be scattered around the city. Time credit would then be taken as a fee for users that want to dock their bicycle anywhere, and given to users as a reward for placing their bicycle in one of the charging stations. Such a measure would make for a much more flexible network. It would however contradict one of the most fundamental virtues of the Clear Channel system: its simplicity. The system finds its succes in the fact that it's incredibly intuitive and simple to use. The next generation should, if one thing, preserve that functionality. A feature such as time credit should provide a nifty surplus, or a more interactive experience for the user, but it shouldn't interfere with the core feature of the network which is riding a bicycle between two station. It is a gamifying measure, and the next generation bike sharing network, as with all successfu games, should be enjoyable for the most intellectual of beings, but understandable to even the biggest idiot. It should never be obligatory to the user to participate in the time credit feature.

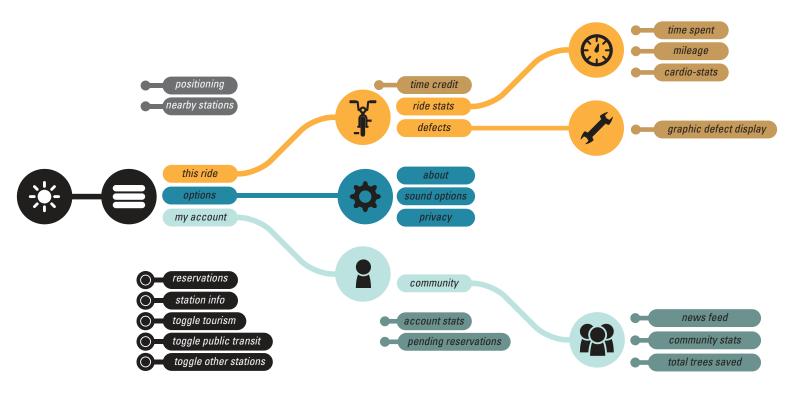


Figure 41: Schematic representation of the Digital Platform interface

The Road Map Screen

The positioning road map will be the central function of the application. Upon activation, after the startup splash screen, the road map is the first item displayed to the user. The main purpose of the road map screen is of course the positioning feature, and the ability to track nearby stations. The user can then select nearby stations, to display an information panel with the available bicycles. The user can check how many bicycles are available for immediate use, how many bicycles are occupied by pending reservations, if there are any defected bicycles or bicycle docks. From the station information panel, the user can also make his own reservation, even if no bicycles are available at the time. More information about the reservation functionality can be read in "Reservations" on page 121. The menu then branches off into three submenus, relevant to different functions, both offroad and en route.

Active Ride: This Ride Branch

The active ride branch displays data relevant to current ride. These include time ridden, time left, credit settings and more. In a later phase of design, if at all possible, a feature may be included to check the active bicycle's battery status directly on the application, and this would probably be located in the This Ride branch. Lastly there is also the graphical defect report function. In this tab, the user can signify possible defects using a schematic depiction of the bicycles. Defects notified by users are immediately sent to dispatch, who can then either equip regulators with the appropriate replacement parts, or have it picked up and stored for more in-depth maintenance measures.



Figure 42: Integrating tourism applications may encourage touristic destinations for system implementation

Options Branch

The options branch is a generic branch meant for the more standard functions. This submenu enable the user to switch off the sound, read general information about the service, and switch up his privacy settings. Privacy settings includes whether or not the system keeps track of your routes for service improvement.

Account branch

The account branch displays recorded data. The user can watch his total mileage, time left on his current user license, and more. Pending reservations, if any, are also displayed, and can be cancelled if desired. The account tab also gives access to a small community panel. This little submenu displays community collected statistics, such as carbonemission prevented by the community by doing miles per bicycle instead of by car. There's also a blog/newsfeed about novelties in the service.

15. Conclusion: System Design

15.1. A Summary

New products planning introduced the three touch points that gave shape to the objective for the system design phase. These points of interest each were treated and elaborated upon with a view of their role in the final phase of the master's thesis process: product design. The smart device application interface was approached from three different angles, one being the user lifestyle aspect. Different possibilities were explored as to how the cyclist lifestyle might be enhanced using the application. Secondly, there was the product aspect, which focussed heavily on the bicycles themselves, and how increased efficiency and ease of use could be achieved. Thirdly, features of benefit to the service and regulation instances were explored. These three angles of approach eventually cumulated in a schematic depicting the different functions, and how they can be accessed by the user. The station's critical factors were indentified and much like the bicycle a 3d schematic model was made depicting their location and size. The necessary subsystems were designed and verified and eventually led to a proven concept for a modular station that can double in capacity, and can even be moved with bikes on it. All this can also be at a relatively low cost. The lifespan of the bicycle batteries was verified, a bicycle locker with charger functionality was designed. Other than a revised power setup, and possible esthetic changes, the stations will be kept at this level of concept. The bicycle's main components were defined in terms of size and technical specifications, and visualized in a 3D-schematic model. The functionality of some subsystems, listed as critical factors during the New Products Planning phase, was also developed on a system level, to be materialized during the final stages of the project. The option to lock the bike to temporarily lock the bicycle in the middle of a bikeride would initially be included as a key component of the new bikes. However, it was repeatedly pressed how the philosophy of Clear Channel Belgium contents that one always finds a stop in the immediate vicinity (300m), so it is not necessary to provide an additional slot on the bikes. After long consideration has therefore decided to discard the feature.

15.2. On The Verge Of Product Design

The macro design phase has been completed at this point in the project, the gross logistical lines of the system are set. The final stages of the design therefore caters to the meso and micro level, id est the service features and the product itself. The product phase responds to the same three touch points of which the foundations were laid in system design. These are elaborated further, each to a relevant level. The bike is further specified into a semirealistic model. The charging infrastructure and the carrier will be explored further. Furthermore, the general production of the frame will be covered, and the motor assembly is determined.

The station, as already mentioned, is elaborated upon at the system level, with respect to the power supply of the station lockers, general structure, and aesthetic value. Finally, there is the digital application, which is deviced in regard to user interaction. An ergonomic base model will be established with a clear graphical form language. Then, some screens are to be developed which play a key role in the interaction with the application. In conclusion, an interaction road map will be drawn up in which the various screens, and how they are intertwined, are displayed.



product design

The final chapter focuses on the completion of the previously stated touch points, each at a respective level defined in the system phase. The bike was to some extent developed at product level, with the necessary components defined and critical systems materialized. The station was held at the system level as scheduled, but was further developed in terms of power supply, ergonomics and aesthetics. The smartphone interface was outlined through the visualization of screens that play a key role in the user interaction.

16. Building The Station

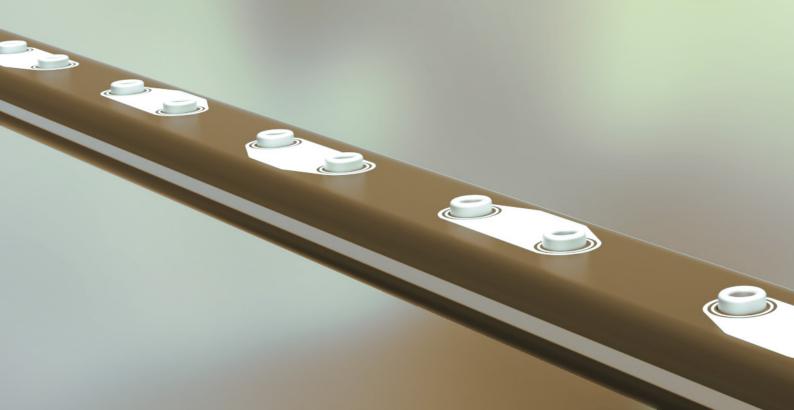
this chapter discusses the further development of the station system. While the station was kept at the level of concept rather than being developed into actual product, significant features were looked into, and discussed in the course of this chapter.

The Station Structure

The station structure was revised during the materialisation process, mainly due to the fact that it would become an overcomplex puzzle in terms of powering the stations and the smart electronics such as drivers and logic gates can only support a certain amount of lockers. The maximum number of modules to be chained together was therefore set to 2, granting the option to double capacity for stations from 12 to 24 bicycles. If a greater capacity is required, multiple stations may be placed in close proximity to each other at a single location.

Station Kiosk

The kiosk in the centre of the modules consists from two basic metal struts for structural purposes. In which plastic inserts can be fit on both sides, with functionality depending on the wishes of the service. Modules exist with user access panel, but also a plain black panel, or a printed on panel for commercial or informative purposes. In this concept, all modules are equipped with a similar sized kiosk. The functionality of the kiosk may vary between modules, but the dimensions remain the same. Of course this not a critical factor, and shorter kiosks might exist on modules which do not require user access interface or signalling functionality. To add further functionality to the kiosk socket, the dynamic modules could even feature a billboardshaped kiosk built solely for advertising purposes.







The Fixed Module

The base of the station will consist of a permanent module, which receives power supply from a fixed outlet on location. The user kiosk, which users can access to obtain a bicycle, will always be present on this fixed module. The module itself however, like the dynamic variants, will not be fixed to the ground by any means other than its shear mass. It does not require trenching or excavation of any sort. The module offers space for up to 12 bicycles, determined by both the size of the bottom plate, and the capacity of the power grid.

The Dynamic Modules

Every station will house possi bility for the coupling of an additional module with capacity for another 12 bicycles, effectively granting the option for doubling the station's bicycle capacity. A separate power supply runs from through the fixed module beam and provides power for the extra module, which can be connected using an industrial power cable. These dynamic modules generally will not include a kiosk, instead the middle beam will serve as a signal post for station visibility. It has fewer smart components than the fixed module, and no fixed power supply of its own.

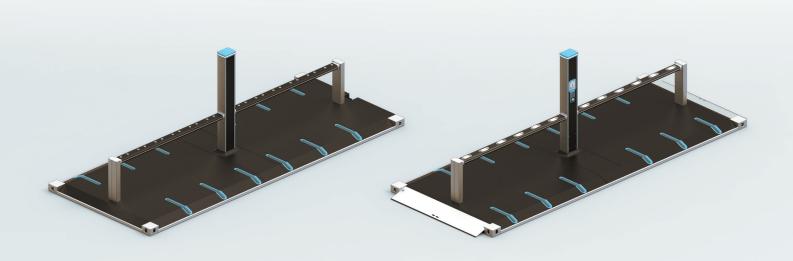


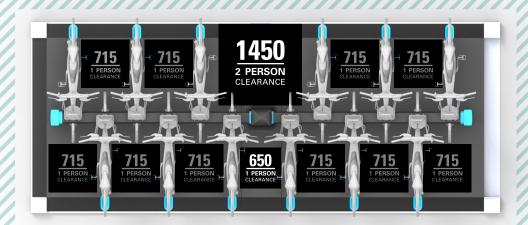
Figure 43: The dynamic module (right) and the fixed module (left)

Roofless Stations

The decision to place or not to place a roof structure onto the modules took careful consideration. Even though it seemed a good idea to let the dimensions of the entire cargo container shine through in the structure of the dynamic stations, and to simultaneously refute the problem of wet saddles, the notion was discarded in the final stages of the design process. This happened due to the fact that the modules would have on the street, which is not always desirable, especially in tourist destinations. A very heavy impact Furthermore, the regulations were imposed by urban planning at almost all locations lead to problems. Therefore, the final station does not include a roof, although the structure could be easily mounted on the module if specifically asked for in an implantation plan by the client.

Station Zoning and Clearances

Due to the final version of the stations being double-sided by default, placement against walls or on street borders is not advisory. The area around the station, or chained station modules, will ideally be 1350mm or more, so that two persons can comfortably pass each other by. The capacity of a single module is twelve bicycles. Between every bicycle, the minimum space requirement for one person passing through (650mm) was respected. The bicycles were furthermore placed so that the space in front of the kiosk allows for two people to pass each other straight on without discomfort. This area also grants access to a maintenance hatch in the lower part of the kiosk. Therefore the 1450mm clearance will also allow the maintenance crews to perform the necessary repairs or modifications to the station kiosk's internal components with no discomfort.



1350 2 PERSON CLEARANCE

clearances in mm

Figure 44: Dynamic Station walking clearances

Sheetmetal Covers

During the course of system design, the steel covers were attached and fixed using simple anti-vandalism screws. Since the roof was later abandoned as a design item, however, this solution was difficult to implement in a subtle manner, as the roof support columns were used for the screw sockets. Furthermore, the fastening bolts seemed like a clumsy solution, slow and unreliable. In the belief that better options existed, a simpler mechanism was searched to quickly fix the coverplate. Ultimately, a system was designed, based on a simple lock and key, which would be present on either one side, or on both ends of the sheetmetal parts. Locking or unlocking the mechanism will render the plate able to adjust its angle. Ball-snaps indicate the preferred stance of the sheetmetal covers, these may then be locked in place by twisting the locks. Figure 47 on page 135 pays a closer look on the principle.

Station Electronics

A current of 440V is delivered through a fixed power outlet underneath the access kiosk of the fixed station module. In this access kiosk are located the necessary converters, as well as the smart electronics required to power the module and a possible adjacent dynamic module. A module, fixed or dynamic, consists of 12 lockers. Every powered locker means a resistance of approximately 0.1V on the power supply to the next locker. To allow for efficient power supply across the entire module, a total of 12 lockers will be included in the module. This number is based of the capacity for the current beams, which already have been proven to work in an effective manner. To supply power to the second, dynamic module, a second power supply cable runs through the station's baseplate. The other station can be connected to this power supply through an industrial coupler. The connection is protected from harmful weather and nightlife conditions by a simple coverplate, fixed shut with bolts.

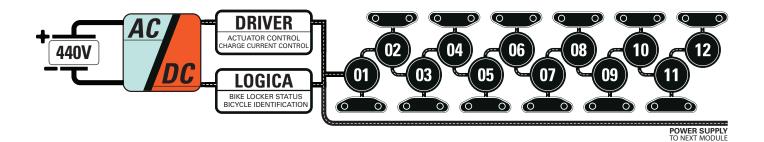


Figure 45 : Schematic depicting the fixed module power layout

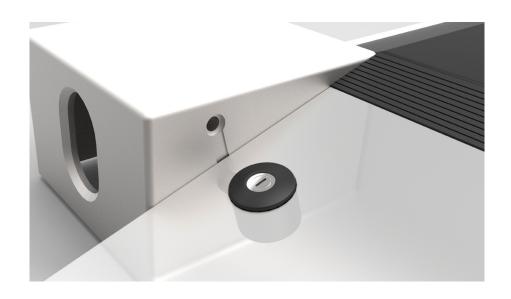


Figure 46: See-through detail of the station sheetmetal cover, depicting the new locking system

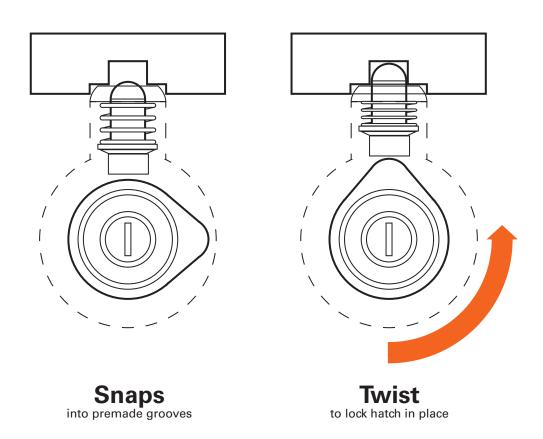
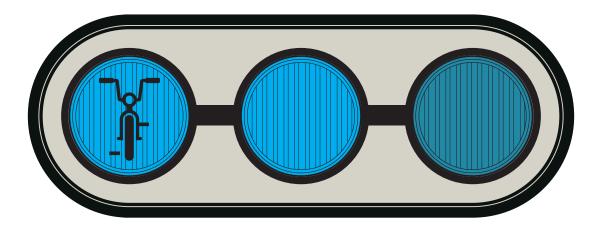


Figure 47 : Schematic representation of the connector lock



BICYCLE AVAILABLE

UNOCCUPIED LOCKER

OUT OF ORDER

This locker has an active bicycle stored

This locker is free for bicycle returns

This locker is inactive/ defected bicycle

Station Signalling

The new station requires a clearly visible signal to make it easier to find, particularly at night. For this model, light signalling with simple iconography was considered as the most direct and responsive way to communicate bicycle availability to the user from afar. This simple signage would consist of as many lights as there are bike lockers are present in the station. Each lamp may light up in different ways. The first mode displays a symbol of a bicycle, and signifies that there is one bike available at the station. A second mode illuminates the whole lamp light, and indicates an empty locker where users can post their bikes. An extinguished light signal means that a defect exists in one of the lockers. A fully extinguished station therefore signifies that the whole station is unsuitable for use at that time.

Simplified Signalling

A simplified model, recommended by Clear Channel for cost, no longer existed from the full twelve lamps, but instead used only 3. A first light signal points out the presence of bicycles at the station. A second optical signal, when lit, signifies the availability of free lockers at the station. A final light signal signifies a defect at the station, remotely informing the user if a station has placed out of order. The concept was toned down even further later on, and used a two-parted light signal which could indicate bicycle availability and locker vacancy. The lamp which would indicate station defects was left out, and instead the other lights would simply colour red if there ever was a defect.

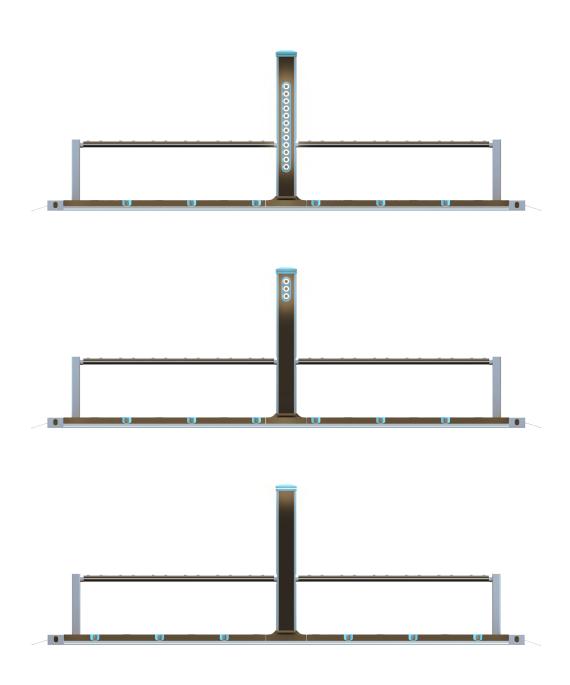


Figure 48 : Three visual displays on the stations of different signalling solutions

16.1. Materializing the Lockers

Insulation

It was decided to retain the metal base for structural purposes. A plastic insulation bath provides the necessary insulation for power transmission safety. The locker's axis is divided into a number of pieces: a plastic buffer component on either side of the solenoid actuator, and a metal conductor, on which the power supply of the charging infrastructure is mounted. When an electric bike is recognized by the RFID scanner, the charging current is guided through these conductor endings into the anchor points of the bike, as already discussed in the system design phase. The current is further guided through the anchor points of the bike. This is done by means of a wire clamped to the anchor points which is then guided along the rack into the frame of the bicycle. This initial connection could be achieved directly through the tube of the bicycle, or using an external profile that the wiring may run through.

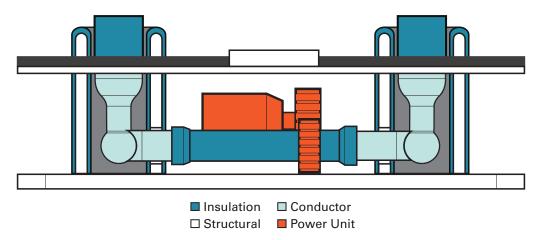
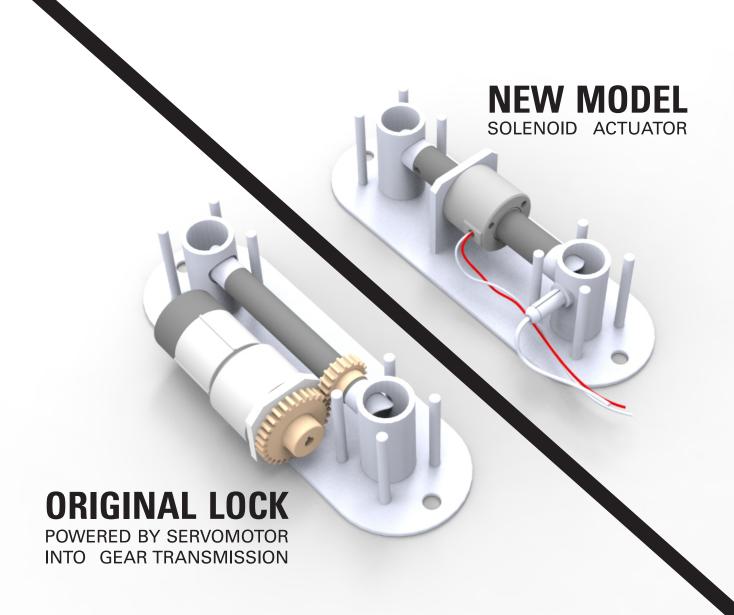


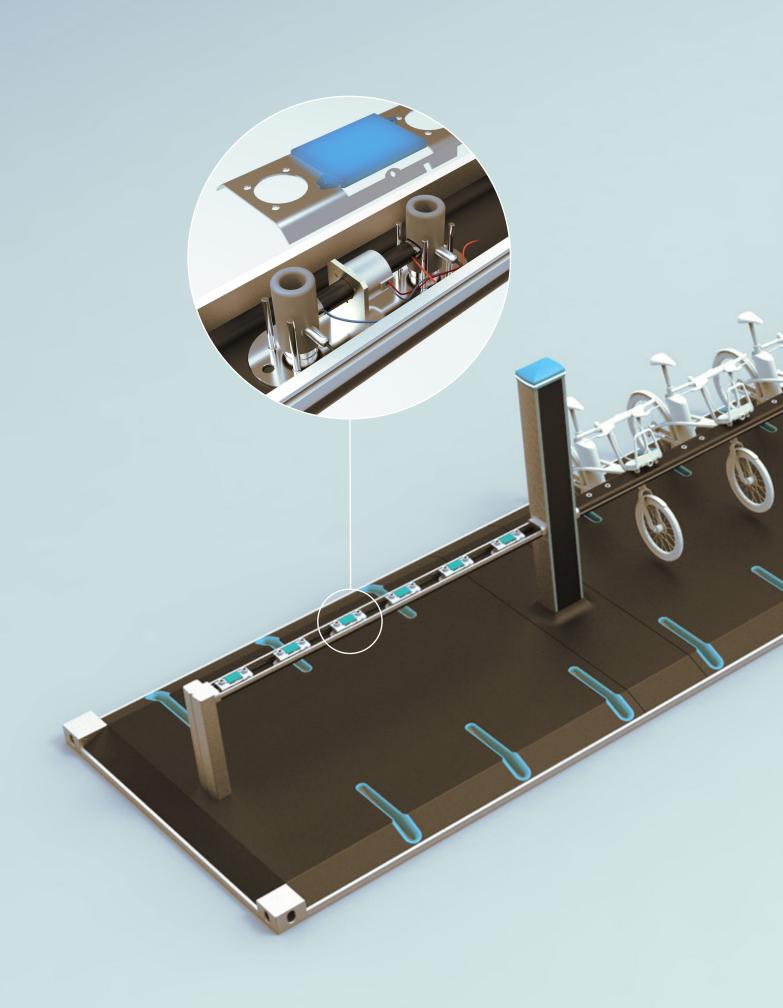
Figure 49: The general layout for the materialised locker

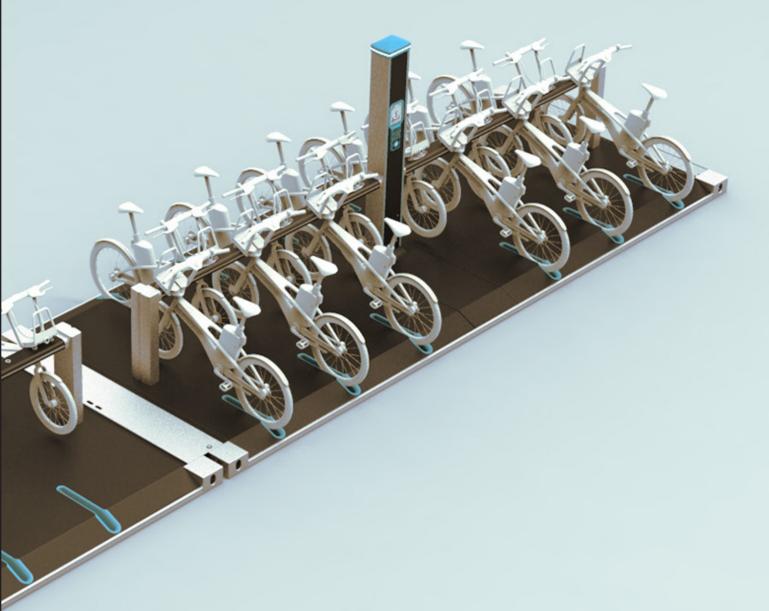
Replacing Gear Transmission

The gear transmission, as shown in this configuration, was replaced by a solenoid actuator, which with fewer components allows for the same functionality. A solenoid is basically a coil that, when introduced to a current are caused to expand, which brings about a mechanical action as a result. However, a solenoid, being coil-shaped may be powered for only a limited time before they become overheated.

Therefore, the electronic mechanism would have to be adjusted. Instead of the current situation, in which the actuator of the locker shall be in open state while inactive, the locker-axis would have to be closed at rest. When the RFID -scanner then detects a bicycle, the axis would be simultaneously opened for about ten seconds. When this period expires the locker shaft returns to its closed default position.







Optimized Flexible

Via smart device application, or telephone hotline, users can obtain a bicycle straight away, without the need for a smart-card. Members that activate the application are immediately prompted when in the vicinity of a station. Furthermore there is the option for users to book a bike ride up to 24 hours in advance, great for commuters on a tight schedule.

Simple

The lockers have a similar user interaction as the original version, so that the transition from the one generation into the other is not too abrupt. They are also compatible with both the new, electric bicycles, as the old models. The RFID scanner bike lockers distinction that bicycles must be equipped with a charging current, and which are not.

The stations each have a capacity of twelve bicycles. Due to their modular construction, they can be expanded to a capacity of 24 bicycles each. The cost to set up sites for multiple station is small because of the limited requirements for implantation. The stations are not fixed to the ground, but are restrained by their own weight.

Mobile

The dimensions of the station, 5.9mx 2.4m, are based on those of a freight container for shipping industry. Thanks to this dimension, they are compatible with most trucks and crane vehicles. The decently sized station base provides support for the full bicycle model, allowing them to be allocated along with the stations.

17. Designing the Bicycle

The materialization phase was mainly devoted to the design of the new bicycles. Although system design presented yet a vague impetus as to the shape and production of the frame, materialization carried new issues, technical challenges tied to the detailed design of the components. The following chapter presents the design decisions and progress during the product design phase, both on a technical scale, as the aesthetic quality of the bicycles.

17.1. Design Direction

The bicycle design should be representative of the positive future image of the city in which it operates. However, this image must also reflect a certain charm, a special kind of retro flair that is hard to describe in words. Therefore images, in the form of a moodboard were used. Inspiration was sought in the vintage automotive industry, among others: car brands like Jaguar and Porsche. The design language of this type of transport is highly dynamic, but with a familiar form of class that strongly dominates the city bike culture today. The design of large surface areas, as well as details of custom made components were designed for the most part according to this particular style. Old racing bike culture was a second major inspiration because of their simple, slender build. Finished with leather details and chromium these bikes are the luxury car brand of the velo culture.

Then there's the Smartbike-Aspect, which determines certain functions on the bicycle, as well as major dimensions. These outward aspects, as well as the necessary security features will have to be combined with the new design direction in a tasteful way. It was decided to combine the vermilion colour of the standard smart bike with a stylish black. Some features could be highlighted to give the bicycle a more dynamic appearance. At the same time it was important that the charm of the classic city bike was clearly felt in the design. Therefore the general body structure of the bike was left unchanged, and the static saddle tube was given extra emphasis by adding volume for the electrical components.

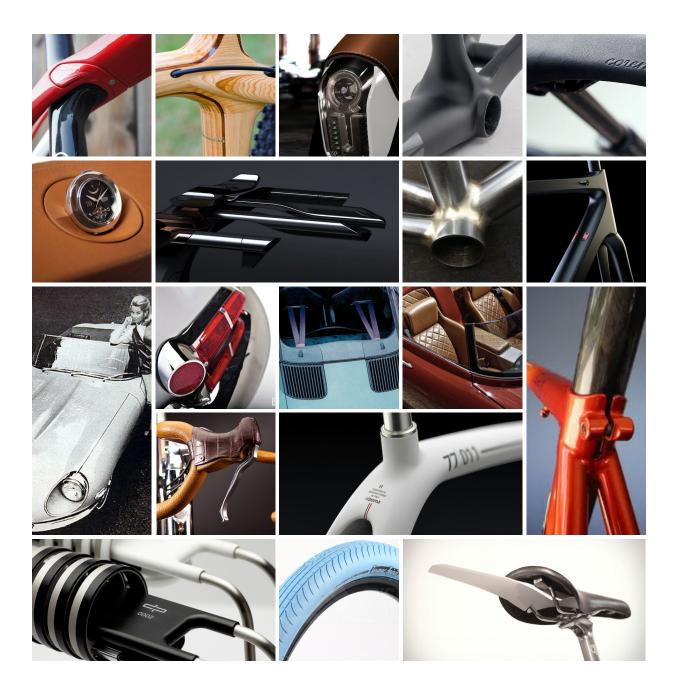


Figure 50 : Guiding moodboard for the general design language

17.2. Designing The Bicycle Frame

Pot Lid Model

A first model featured a simple frame consisting of welded alumnium components, both extrusion-formed and hydroformed. Aluminium was chosen as the primary material for production due to it's lightness. An aluminium frame as opposed to a full steel bicycle frame very nearly cuts the weight of the frame in half. The conspicuous centre casing, which houses the battery component, as well as the saddle assembly gas spring. This casing would be fixed on the rest of frame via welding, and thus would be unremovable but for the top part, which can be unscrewed and lifted off the rest of the bicycle, much like a pot lid. Maintenance crews would then be able to reach into the casing, and access the electrical components. This opening mechanism seemed adequate for maintenance purposes at first, but was later revised.

A reimagined model

A new frame model was made, using fewer welded components for increased material strength. The component casing was split in two near-identical shells that are fixed together around the saddle tube. Because the shells can be removed entirely, maintenance is granted access to the entire battery component, as well as the wiring and motor unit, which can also be replaced with greater ease than was the case in the original frame design.

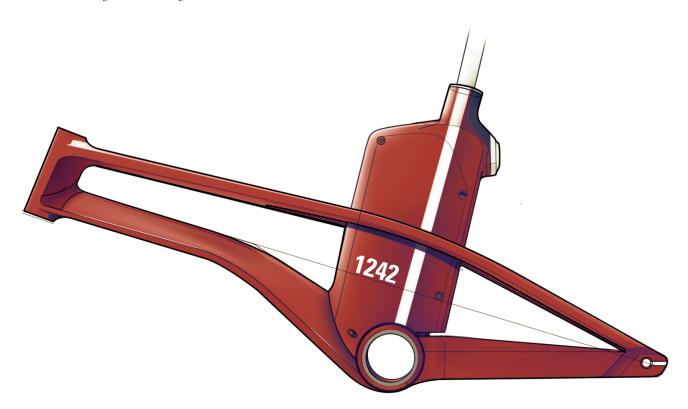


Figure 51: Key sketch for the bicycle frame

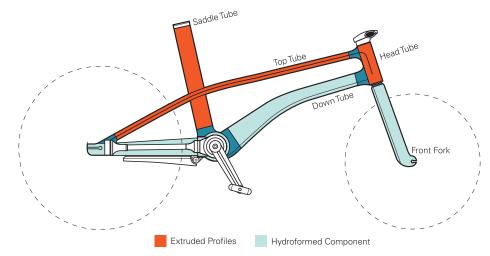


Figure 52: Production of different frame pieces

Components

The frame, as well as the other structural components for the bicycle, has several possibilities in terms of production beyond simple extruded tubes connecter through welding. The casing of the battery components was to be produced through sheetmetal forming. Hydroforming was chosen as the preferred production method, due to its relatively low production cost. Hydroforming would require only one mold for each of the shells. Therefore, for aesthetic value, some of the structural tubing was also produced using hydroforming techniques. Various scenarios and degrees of technology could apply here. A big hydroformed tube component could make up the head tube, connect into the down tube, and curves back up for the seat tube. Thanks to hydroforming technology, these three parts are made into one main structural body, with greater strength and durability.

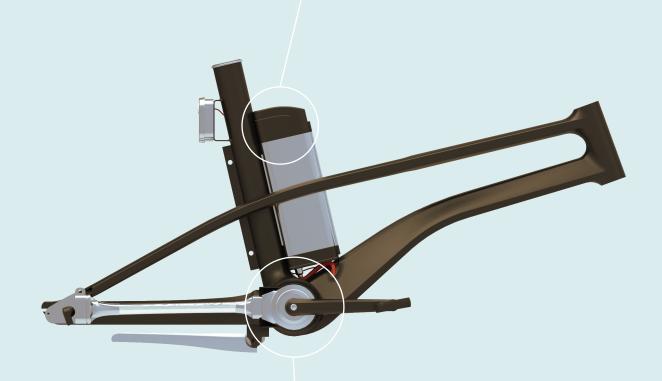
These components would exist from a single tube, which is first bent into the right configuration. The bent tube frame is then hydroformed between to molds to create the character of the shapes. The new frame would then be built from 5 welded structural parts, down from 10 in the original smartbike. However, as the effective production number may vary between 4.000 and 20.000 pieces, this is kept as a simple suggestion. The frame, as illustrated in the figure above, is built from all separate components. The top tube, in the Smartbike tradition, is made out of two thinner tube components, that are welded together in the front section. The weld membrane is then polished until it blends the tubes seemlessly. These top tubes stretch all the way back to the rear wheel, but are not connected to the actual frame past the centre casing, except for a small welded plate on which the rear mudguard is mounted.

Silverfish Battery



Voltage 12 Volt Capacity 20Ah Charger Current 5A

Mounted upon the seat tube Connected through the frame with the charger assembly



Coaxial Motor



Voltage 12 Volt

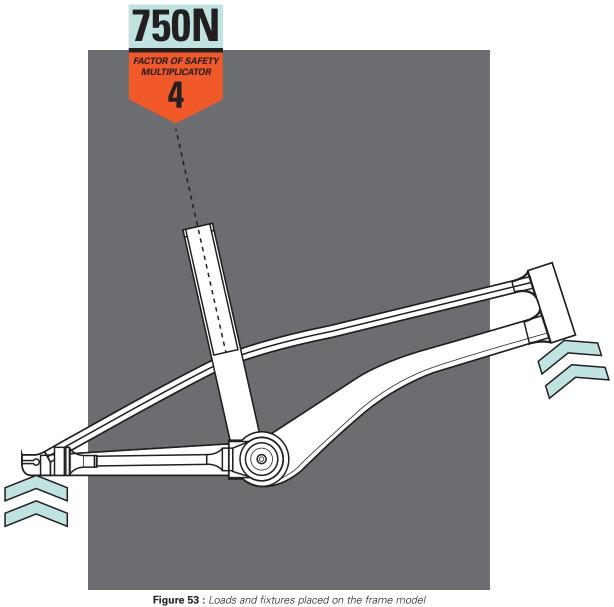
Internal Drive Shaft Transmission Conventional ebike motor unit

17.3. Structural Analysis: Bicycle Frame

Since the frame has undergone major changes both in form and structural quality, compared to the old model, one cannot allow these changes to go without certain validation in terms of strength and stiffness. Using SolidWorks Simulation, structural loads were tested on a simplified model of the bicycle frame. The main load was based on the weight of an average European man, 75 Kg. Since this product is a means of transport, which also performs a load-bearing function for human beings, a large factor of safety of course required. This was set at a multiplication factor of 4. This means that the frame will have to be able to withstand static loads of up to 300kg. Thickness for the aluminium profiles and shell components was set at 1.5mm, but later increased to 3mm, when aluminium became the prime component for the frame. Three millimeters may seem like an excessive wall thickness, but it's actually a rather conventional thickness for aluminium bicycles, aluminium allterrain models exist even with thicknesses of up to 6mm. Increasing the wall thickness may cause a slight decrease the frame's stiffness, but greatly improves tensile strength in return. A bent frame can still be ridden, a broken frame cannot. The specific alloy chosen for the bicycle's frame is 6061 Allloy for it's high flexibility of design options and great forming functionality. It's a common material for the modern bicycle.

"Most manufacturers of alloy high-end frames in Taiwan use 7005 as the material of choice, whereas China-based manufacturers will mainly employ 6061. Neither grade of alloy is "better" than the other in an absolute sense. It simply depends on what your purpose is. One property of 6061 is that it is more malleable than 7005—it can be more easily "drawn", opening the way to creating a variety of tubing designs through hydroforming processes for example. It is also more resistant to corrosion and fatiguing." (Satincesena, 2010)

The model was simplified to facilitate the simulation process. Cosmetic fillets used to simulate weld seems were ignored, as well as smaller sheetmetal components with no structural bearing functionality. The main load, illustrated as a force of 750N was applied as a remote force on the base of the saddle tube. Two fixed geometry points were determined: one on the fork of the bicycle, and one in the rear wheel socket of the bike, as shown in the figure. This is but an abstraction of what the actual impact on the frame will be, but it provides an image of structural strength before investing in the construction of an exact physical prototype.



Factor of Safety Analysis

After assigning the necessary loads and fixtures to the model, a number of result plots were issued. One of these is the very practical analysis tool for Factor of Safety verification. For the high factor of safety that this model requires, visual feedback from a tensile strength analysis will not provide conclusive information whether or not the factor of safety is maintained on even the smallest joints of the bicycle frame. The factor of safety plot adresses this feature, it automatically checks the model for a given factor of safety, and highlights all areas where this factor is not met in a bright red teint, as opposed to the dark blue default colour. As demonstrated in the figure below, a manipulated model, with wall thickness set consistently to 1mm, fails the test. The bright red areas clearly indicate the points where the bicycle frame does not meet the safety requirement. The actual model, with 3mm as the wall thickness, evidently passes the test. Out of sheer interest, more tests at different thicknesses were conducted, driving up wall thickness by 0.1mm at a time to check for the thickness at which the factor of safety would be met exactly in every point of the frame. Suprisingly enough these conditions were met only at a thickness of 2.9mm.

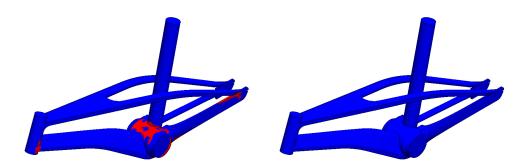


Figure 54: The two factor of safety plots for a wall thickness of 1mm (left) and 3mm (right)

17.4. Hiding the Cables

Added Value

A big challenge, and major time investment for the materialization process was hiding the cables on the bicycle. These sensitive components are not intended for continuous use of a public service. They are often the victim of rough users, or broken in acts of vandalism, and therefore must be regularly replaced or repaired. To increase the durability of the bikes was therefore decided to foreclose. Wiring all user This includes the cables for charging infrastructure, but also the brake cables, and power for the bike lights. Although it wasn't included in the original design scope, this proved to be an issue that could not be neglected.

Front Fork And Rear Wheel

It is not always necessary to completely shield the cabling from the user. Often, it is sufficient to make certain cables difficult to reach, so that vandalism is discouraged, while keeping them relatively accessible for maintenance. This can be achieved by placing certain components in the way, as is the case with the fork and the rear wheel. In these pieces the cables are hidden in subtle grooves, hiding them from view. By unmounting the wheels these cables become accessible for possible repairs.

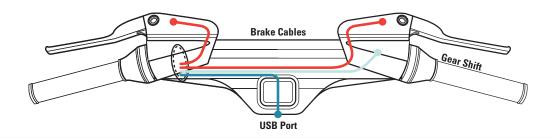


Figure 55 : Cutaway view of the bicycle's fork, with blue wiring tucked into subtle grooves

The "Dashboard"

There exist a number of networks in which the handlebar is shielded by means of a cap in plastic or metal. These clumsy volumes tend to be oversized, rendering the bicycles ugly and using more resources than is necessary. A cover would have to be as light as possible, both in terms of mass and shape language. The bicycle frame is a delicate, slender structure. A plump volume such as a heavy shell would draw the proportions of the whole product completely out of balance. So a hood had to be devised that was able to cover the cabling from the brakes over the handlebars into the actual bikeframe, an this structure would have to be both light and subtle. A shape was devised that greatly resembled the dashboard of a car, hence

the working name . The dashboard consists of two plastic shells that can be placed overtop the steering handle, and fastened with bolts. Cables are guided through the shell, and into the iron mullions of the bike handles, where they are then conducted to the fork and the actual bikeframe. Through means of the dashboard cover, the handle itself, as well as the steering assembly structural components retains their lightness and openness. Within the frame, cables are guided through the straight down tube, and connected to the battery component, as well as the dynamo-powered rear light. The bicycle's centre component casing covers both these components and the frail wiring that connects them.



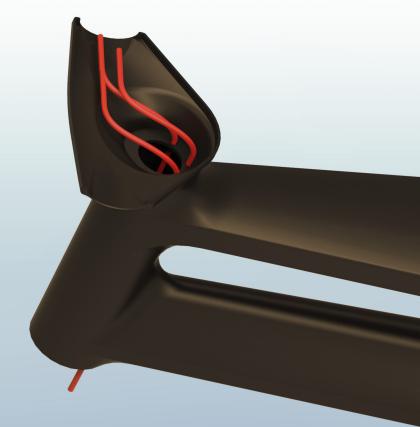


Figure 56: Dashboard wiring

Figure 57 : Schematic representation of the head tube wiring and handlebar clamp

Luggage Rack

The luggage rack was styled so that the old shape would be still recognizeable in the design. The general structure is much more complex than the original model, due to the wiring of the charging cable having to be escorted from the locker anchors into the bicycle frame. The model that was eventually chosen, consists of two steel shells, which protect the locker axis and associated wiring, as well as the bicycle front light. The lower shell, a sheetmetal piece, is fixed on a support structure of hollow tube sections with welded joints. This piece also provides the hinges for the swiveling shaft locker. A second piece of steel functioning as a coverplate, and carrier for the user's luggage, is fixed on this lower shell piece with anti-vandal bolts. This is in effect the protector component for the locker axis and wiring for the charging infrastructure and the bicycle light, and can be removed in case of repairs. The sheet also includes two appendices that contribute to the locker swivel axis being held in place. It should further be noted that even if an abusive user manages to remove the cover, although he could reveal the wiring, he cannot steal the bike as long as it is still in a locker. The locker axis is fixed in this way that it can not be detached from the rest of the bicycle without the use of a sturdy iron saw, and using such a saw would mean to destroy the charger infrasructure, thus making the bicycle pretty much useless. A maintenance crew, however, if the bike is legitimately removed from the locker, can easily remove the locker axis to impart necessary repairs or replacements. The luggage rack was also tested for tensile strength. The simulation includes a simplified version of the luggage, isolated, with both anchors fixed as if they were locked in a station.

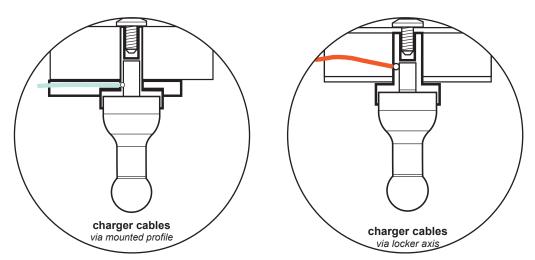


Figure 58: Technical sketches of charger cable protection measures within the luggage rack



Figure 59 : Cutaway view of the luggage rack

In this simulation, a user exerts his strength, 1000N, from the two handles of the bike. Since there is no bicycle frame is attached to the handles for the simulation, there is no additional support to absorb these forces. In other words, the simulation examines purely the strength of the rack. As can be seen in the figure, it easily withstands the test, only on the anchor itself a point of tensile yield may be noticed. This is due to the fact that the locker shaft is non-rotatable, in order to make it compatible for simulation. In reality, this is the case, and the rack therefore creates less strain on the anchor points.

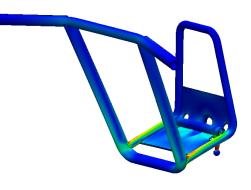
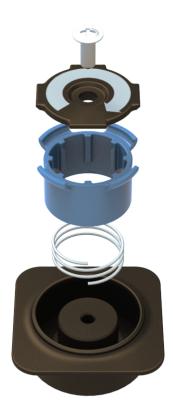


Figure 60 : Luggage rack strength diagram

17.5. The Smartphone Socket

The locking system was further specified, using the existing Quadlock smart device mount as a reference. The system works thanks to the blue slider, held in place by a spring component and the black fixed mounting piece. When the slider is pushed downwards, by fitting the smart phone or tablet over the lock at the right angle, the device can be locked in place by rotating the phone back to the right position.

The user may then release the slider, which is thus again forced upward, and in that way it clamps the mobile device onto the handlebars. As a final feature, at the bottom of the dashboard there is a USB port that can charge the user's smart device if he/she so desires. This smartphone fixture is customized to the user's personal model, and can therefore be trusted, even on the more delapidated roads and bumpy tracks.



Smartphone Holder

QUADLOCK MECHANISM

Figure 61: Smartphone holder, an exploded view

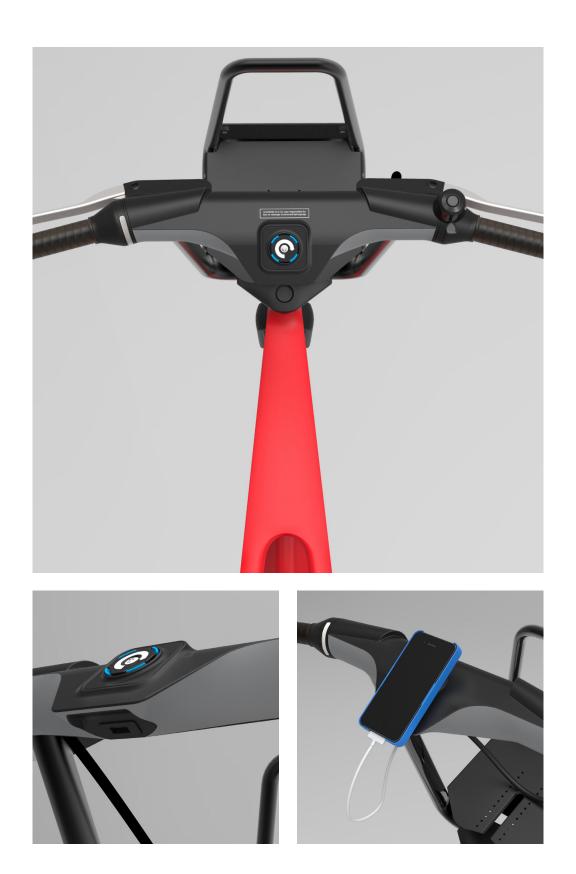


Figure 62: The smart device holder and USB-port

17.6. Ad Revenue Generation

For a system variant that is either fully or partially financed by advertising proceeds, as opposed to government funding or private initiatives, it is obviously vital that the appropriate advertising space is provided on the bicycles so that the system generates the required revenue. A few possible models, some using modifications, were designed to allow for ad placement. A first proposal uses a plastic insert in the rear wheel of the bike. This is a large printable surface that adds a certain style aspect to the bikes, and allows to affix large advertising imprints on a distinctive part of the bicycle. As the new models have a large central volume in the form of the casing for the battery component, there is obviously the possibility to apply small and medium-sized print on this area. The surface is curved so that it allows for the attachment of decals. The new bicycles include a revised design for the luggage rack, provided with a welded piece of sheet metal on which imprints may be applied along the front of the surface. Optionally, the sheet metal could also be punched into a relief logo, or one might even laser cut the sheet to allow for a cutout graphic. Finally, there is of course the possibility to opt for the classic fender surfaces as a medium for generating advertising revenue. Even though in the new design more subtle, black mudguards were chosen, nothing stands against the service to equip them with the classic heavy fenders in the case of monetised advertising as a main source of income.

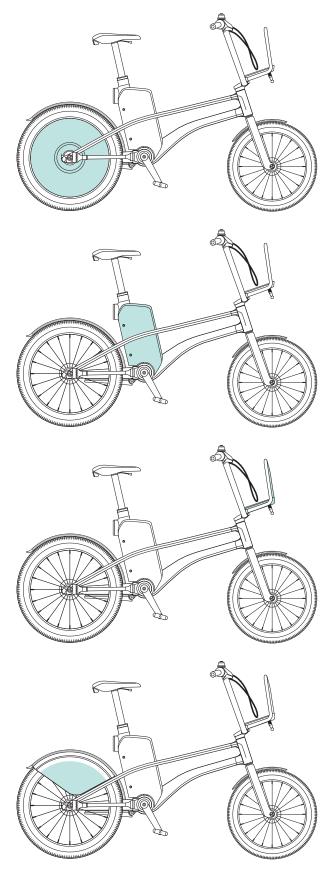


Figure 63: 4 models for advertising placement





A BICYCLE FOR 2015

The model for the new Smartbike bicycle still reflects the trusted brand image of the original. However, the design has been modernized, and was translated into an elegant new version that caters to the booming bicycle culture. Sensitive components such as the battery, the engine, and even lighting elements are concealed in a sturdy metal body that makes up for one of the main form characteristics of the new bikes. The case is easily removable for maintenance purposes, but forms a barrier against harsh weather and damage resulting from the urban nightlife. Another remarkable feature is the utter absence of cabling along the bicycle frame. This choice was

deliberately made to grant the bike yet more durability, and reduce chance for vandalism. The handlebar is equipped with a stylish user console, working name 'The Dashboard', which features a sturdy holder for smartphone cases. At the bottom of the dashboard the user will find a USB-port for charging capability. The saddle adjustment is possible via gas spring mechanism, simply pull the lever below the seat to adjust the saddle to the perfect height. Standardised height markings were also provided on the saddle tube so that users will know, even before getting onto the bicycle, whether or not the saddle is adjusted to the desired height.



18. Visualizing A Digital Platform

The final chapter of the product design phase discusses the graphic user interface for the digital application, and decisions regarding user interaction with this application. The essence of this chapter is the final Interaction Road map, but for clarification, an explanation as to the functionality of different screens and the causality of these functions are discussed.

18.1. General style and approach

The graphic user interface of the digital application, even though this design centres around the service of Velo, is conceived as a general template intended for use across all of the service's running systems. Therefore the layout and interaction design of the interface would have to be a very nonspecific one, compatible with any service application and whatever that network's general corporate style and branding might be. A first design was colourful, and could be customized in colour scheme depending on the service. However, the graphic character and readability of this particular design proved rather heavy after consideration, and this lead up to a new, more rustic graphic approach. The very minimal user interface provides a nice overview of the available functions on each screen. A straightforward button design communicates different functions to the user with ease. A peaceful style was eventually chosen over a more vibrant alternative, as shown in Figure 65.





Figure 65: Two graphic styles considered for the digital application.



"We live on the revolution of both sustainable mobility and mobile devices."

one should not go without the other

18.2. Interaction Ergonomics: Unified Interface

Menu Bar

The interface was built around four centre menus. These are each displayed in an omnipresent menu bar at the bottom of each screen. The four main menus are namely the Road map, firstly, which performs the positioning function and allows for scheduling reservations. A second menu tab displays the current stats of the ride, and is only available when riding a bicycle. The third main menu tab shows a profile of the user, where he can view or cancel his reservation if one is active, and it further displays cumulative statistics and information about the user's cycling behaviour. Finally, there is a main menu branch for options and settings, where one can make general changes to the application, depending on the preferences of the user.

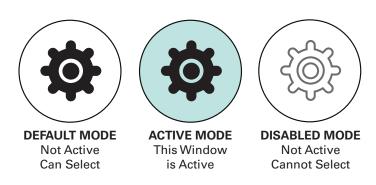


Figure 66: Main menu button semantics

Button Design

The buttons themselves were designed on a very straightforward formula. In addition to the menu buttons, of which only four are present in the entire application, there are also the black buttons, for basic functions that provide access to use of sub-menus and actions. A third category of buttons contain written text as opposed to simple iconography, these unique buttons serve functions that require additional tool tips or can be used to with the addition of subsequent functions for which no graphic yet exists.

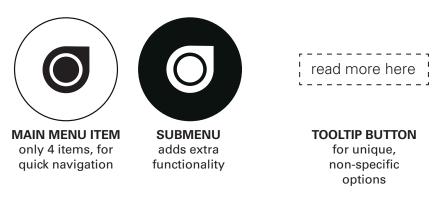


Figure 67: Button type semantics

18.3. The Main Menu Tabs

Map Screen

The map screen is the central element to the application. Its main feature is of course the positioning functionality. Furthermore there is the ability to select nearby stations for information on bicycle availability. The user may also make reservations at selected stations. Lastly, the user can choose to enable display of other public transit stops, such as buses or streetcar stops, and there is a tourist option that displays the tourist attractions should the city system governance require it.

Reservations

The user can schedule a reservation at a given station by selecting the station dot on the map screen, and tapping the clock icon at the bottom left hand side of the map. A reservation interface, shaped like an analog watch, will replace the map screen. The user can then adjust the reservation time by rotating the hands of the clock to the desired position. Once a reservation is scheduled, the user can retrieve it (and, if need be, cancel it) on his profile page.



Figure 68: Map Screen and Reservations Submenu

Ride Statistics

The tab for ride-statistics has the primary function of providing information about the riding speed, and how much electrical power might be provided in achieving this speed. Furthermore, the user can also consult information about the approximate status of the battery. Lastly, there's information to be found on the active time ridden, and the time credit (See "14.3. Regarding Time-Credit: To Gamify Bike Sharing" on page 123) available to the user. This number will phase in and out and will sporadically reveal distance travelled instead of time.

Report Defects

Tapping the wrench icon on the Ride Statistics tab will reveal the Report Defects submenu. In this menu the user can easily indicate where a problem may occur, using a graphical representation of the bicycle. The user can further specify on the nature of the malfunction and can even provide additional clarification if deemed necessary. When returning a bicycle, the user will always be prompted with the option to report a defect on the return confirmation screen.



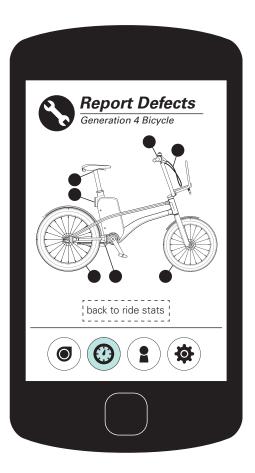


Figure 69: This Ride Tab and Defect Report Submenu

User Profile

A limited profile display is available under the user profile tab. This screen is not intended as a medium for social networking, therefore it does not display a profile picture or photo, and it cannot be accessed by other members of the community: privacy is essential. It only gives the user an impression of his personal statistics, the duration of his current subscription, and pending reservations. From the profile page, the user can also access the community panel, on which general data of the service can be found.

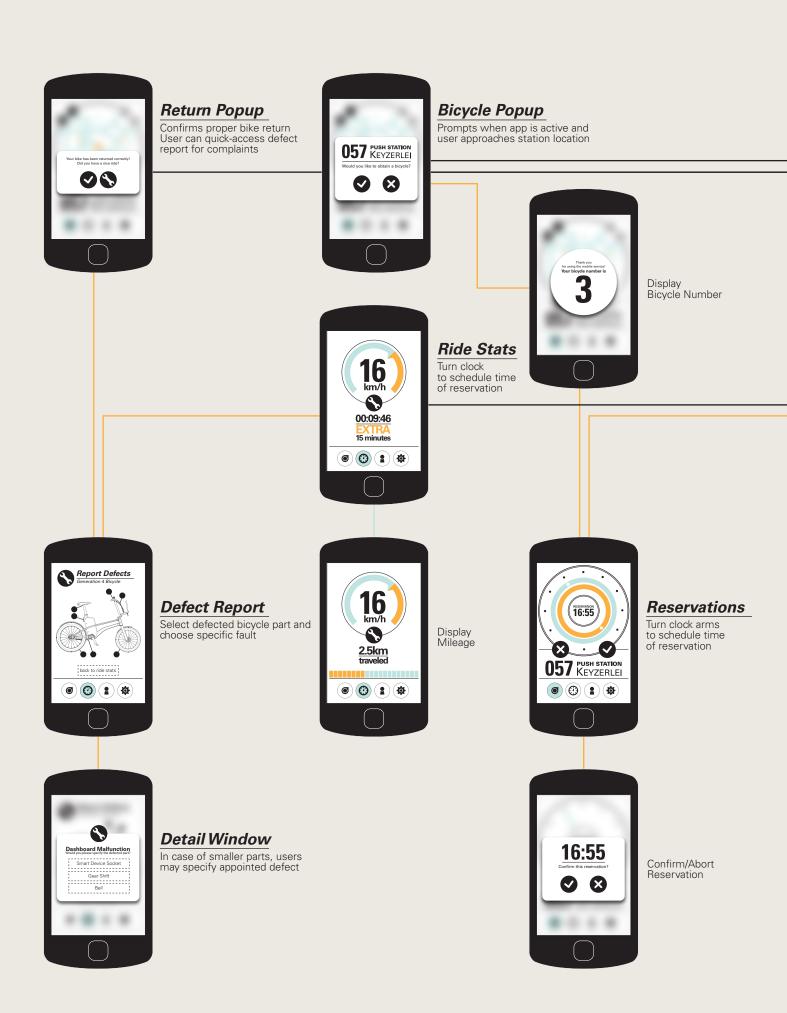
Community Panel

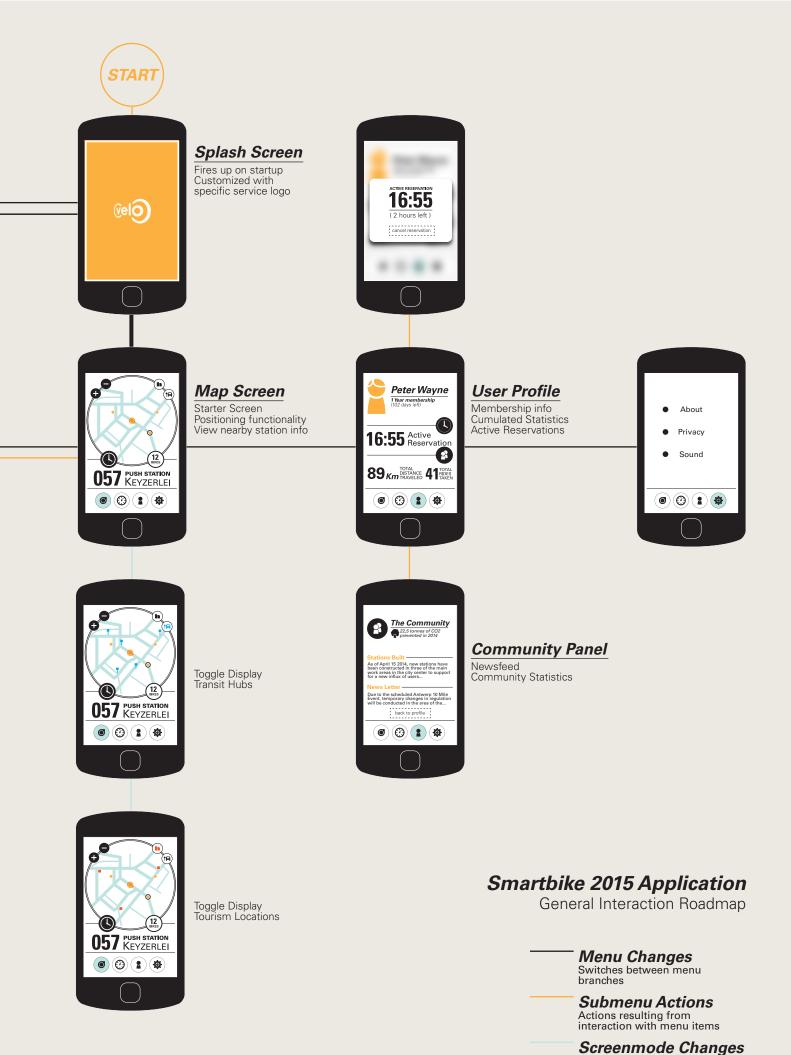
The community panel shows some cumulative data on the achievements accomplished by the service as a whole. Furthermore, there is access to forums, and a 'latest system news' feed, which is continuously updated, much like the service website also includes a news blog. This panel is essentially optional, and its functionality depends on the public character of the specific city-bound service. Should the service be funded by advertising deals, the community page could of course provide great opportunity for extra publicity.





Figure 70: User Profile Tab and Community Panel Submenu





Minor changes within the current application screen.

19. Conclusion: Product Design

The three areas that were addressed in the system phase, were further developed during the product design, each up to the level defined in the previous section. The bikes were materialized to component level and verified in terms of strength of both framework and locking mechanism. The charging infrastructure has been validated, and the correct electronic components were chosen to ensure a smooth running system. Furthermore, it was decided to fully withdraw the cabling from the reach of the user. This decision was not taken until the materialization phase, and required an unexpected time investment, but was enthusiastically received by all parties involved, as the cabling proves to be a serious issue, and therefore the appropriate measures were developed still.

The station was maintained at concept level, but was further refined in design and there was also hinted at how the pieces could be materialized. The product was not worked out in detail, as has already been briefed on new products planning. However, it was verified for ergonomic usage. There also was widespread over the power of the stations and any attached module. Finally, a clear signage was developed so that the stations would be more visible at great distance during different times of day. The supporting digital platform was developed in the form of a series of screens that act as key interfaces for the user interaction. This graphic chart is designed as the visualized result of the schematic disclosed during the system design.

20. Conclusion: Overall Project

During the course of new products planning, attention was devoted to the explosive growth in the market of municipal bike sharing services. Therefore, as a first measure, the history of the bike sharing was studied. The successes and the failures of different networks were discussed, and from these, a number of factors were distilled that, in conclusion, formed the basis for each successful bike sharing system. Secondly, the status quo, the third generation, was researched through a number of case studies, with a focus on strengths and weaknesses of existing services. The combination of the above marked the start of the actual research. Opportunities were sought out in both technological and socio-economic levels. Finally, through thurough research from several viewpoints the Smartbike network in Antwerp was studied: what improvements were deemed relevant, taking into account the current shortcomings of this particular system. After extensive research on the subject, consisting of desk research, a comprehensive user testing, and field research in the shoes of the service regulator, a vision was outlined of how the next generation is possible, could possibly be mirrored onto the system of Smartbike. Thus, the product candidate was determined. This concept catered to three major touchpoints: The main product, the bicycle, primarily an electric version of the original model , would be far more comfortable to use, and should cater to market expansion over new target groups. The station, the infrastructure of the network would feature a charger function to cope with the new bikes 'battery needs, but should yet be compatible with the old models as well, as requested by Smartbike management. Further thought was given about ways in which the stations could more actively respond to user demand in terms of capacity . Thus, the dynamic station became a fact, a light version of the generic station that could effectively double, or halve its capacity over a short timespan. A digital platform supporting an application for mobile devices, is the third and final touch point. The platform was to interlink the service more closely with the lifestyle of the user. Besides a clear positioning display, numerous features make the life of the rider just that little bit more pleasant. For commuters an option was added to reserve bikes during the busy rush hours. For tourists it was made possible to display and review city attractions within the application. These are some of the numerous functionalities that the application weaves into the system. In the final stages of the product design, the story of each of these points of contact was brought to a conclusion in its own respective way. The bicycles were developed into a visually accurate model and its critical components were materialized and verified according to their level of relevance to the project. The stations were developed as a concept with hints of materialization, and a revised power layout between the various modules. The charging infrastructure within the stations was furthermore worked out in detail. Finally, the platform, the digital aspect of the project was visualized as an application with all relevant screens and interactions clearly displayed, and was eventually translated into an interaction roadmap. Together, these three touchpoints, these major actors, give shape to the 2015 version of Smartbike.

21. Final Words

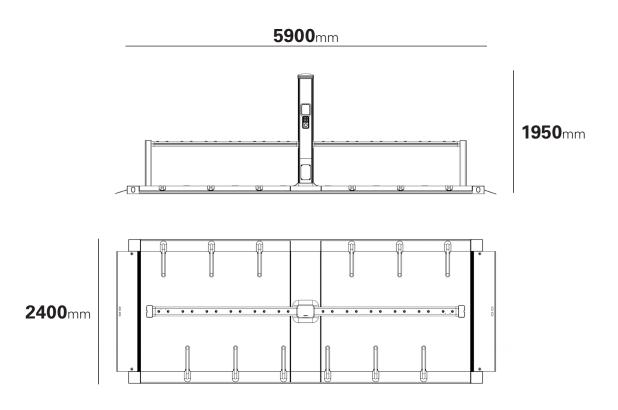
I hope this thesis project has shed light on the complex, yet wonderfully interesting world of bike sharing. This document has the primary function to inspire, and emphasize the possibilities for improvement in the interest of numerous parties. ITherefore hope that you are inspired by the content, not just the final product, but also by the numerous considerations in the earlier stages of design. When an idea is rejected, it does not necessarily mean that it was a bad mindset. The scope of the project was to deliver a concept for how the fourth generation of bike sharing could be incorporated into a network as smart bike. The final product is therefore not a final product, it serves rather as a suggestion, a pick based on carefully considered factors that have made this concept the way that it is. It is an outline of how the network might look like if one were to equip a network such as Smartbike, with viable technologies en utilities of a fourth generation of bike sharing. We live in an incredible era when it comes to technological advancement. One no longer has to look far into the future to formulate significantly innovative ideas. That is the essence of this project. By using viable technology, improving the world of the rider, the service, and the city itself.

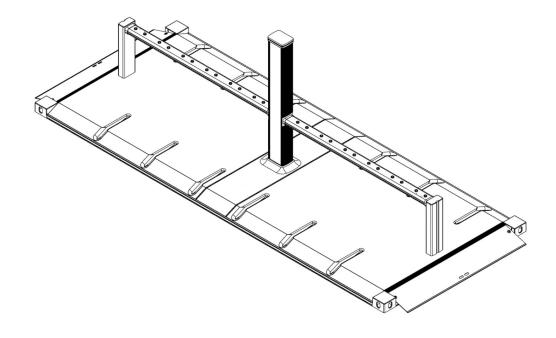
Thank you for your interest.

Fabian Breës

22. Appendix A: Orthographic Views and Overall Dimensions

By means of extra clarification, the relevant orthographic views of the station and the bike are shown here, as well as their overall dimensions.

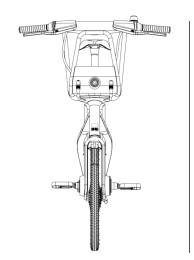




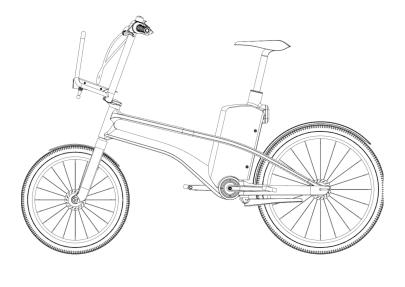
mm

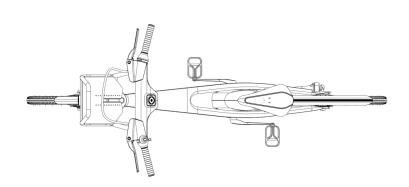
mm

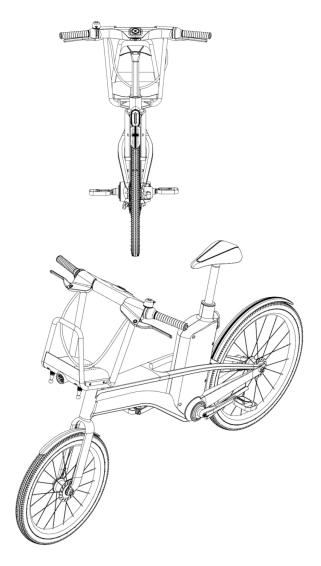




mm







23. Appendix B: Observed Programmes

A listing of the second and third generation programmes that were studied -but not necessarily documented- over the course of the research. In the case of a nation-wide system (e.g. Bike And Roll), or international system (e.g. Cyclocity), the general programme was listed, along with the URL of the overall supplier, and not the city-bound service applications thereof.

CYCLOCITY (INTERNATIONAL)

HTTP://WWW.CYCLOCITY.COM/

VIACYCLE (INTERNATIONAL)

HTTP://WWW.VIACYCLE.COM/

NEXTBIKE (INTERNATIONAL)

HTTP://WWW.NEXTBIKE.DE/DE/

B-CYCLE (INTERNATIONAL)

HTTP://WWW.BCYCLE.COM/

SMOOVE (INTERNATIONAL)

HTTP://WWW.SMOOVE.FR/EN/

CLEAR CHANNEL (INTERNATIONAL)

HTTP://CLEARCHANNELINTERNATIONAL.COM/OUR-PORTFOLIO/CITY-SHOWCASE

PUBLIBIKE (SWITZERLAND)

HTTPS://WWW.PUBLIBIKE.CH/

HOURBIKE (UNITED KINGDOM)

HTTP://WWW.HOURBIKE.COM/MYSITECADDY/SITE3/

KEOLIS (FRANCE)

HTTP://WWW.KEOLIS.COM/EN/BUSINESS-ACTIVITIES/TRANSPORT-EXPERTISE/BIKE.HTML

BIXI (INTERNATIONAL)

HTTPS://BIXI.COM/

CALL A BIKE FLEX (GERMANY)

HTTP://WWW.CALLABIKE-INTERAKTIV.DE/

BIKE AND ROLL (USA)

HTTP://WWW.BIKEANDROLL.COM/

BIKE NATION (USA)

HTTP://WWW.BIKENATIONUSA.COM/

MOBILICIDADE (BRAZIL)

HTTP://WWW.MOBILICIDADE.COM.BR/

EASYBIKE (GREECE)

HTTP://WWW.EASYBIKE.GR

CYCLOPOLIS (GREECE)

HTTP://WWW.CYCLOPOLIS.GR/INDEX.PHP/EN

BYCYCLEN (DENMARK, AARHUS CITY SYSTEM)

HTTP://WWW.AARHUS.DK/SITECORE/CONTENT/SUBSITES/AARHUSBYCYKEL/HOME.ASPX?SC_LANG=DA

BICIMIA (ITALY, BRESCIA CITY SYSTEM)

HTTP://SERVICE.BICIMIA.IT/

CICLOTEQUE (ROMANIA, BUCHAREST CITY SYSTEM)

HTTP://WWW.CICLOTEQUE.RO/

NUBIJA (SOUTH KOREA, CHANGWON CITY SYSTEM)

HTTP://NUBIJA.CHANGWON.GO.KR/INDEX.DO

TASHU (SOUTH KOREA, DAEJEON CITY SYSTEM)

HTTP://WWW.TASHU.OR.KR

BICIELX (SPAIN, ELCHE CITY SYSTEM)

HTTP://WWW.BICIELX.ES

CYCLE FREO (AUSTRALIA, FREMANTLE CITY SYSTEM)

HTTP://WWW.CYCLEFREO.COM/

GIROCLETA (SPAIN, GIRONA CITY SYSTEM)

HTTP://WWW.GIROCLETA.CAT/

BICINCITTA (ITALY, PIOLTELLO CITY SYSTEM)

HTTP://BICINCITTA.TOBIKE.IT

GRAND RIVER PUBLIC BIKE SHARE (CANADA, WATERLOO CITY SYSTEM)

HTTP://WWW.GRANDRIVERPUBLICBIKESHARE.CA/

ROMA'N'BIKE (ITALY, ROME CITY SYSTEM)

HTTP://WWW.ROMA-N-BIKE.COM/

ROWERES (POLAND)

HTTP://WWW.KRAKOW.ROWERES.PL/

YOUBIKE (TAIWAN, TAIPEI CITY SYSTEM)

HTTP://WWW.YOUBIKE.COM.TW

TEL-O-FUN (ISRAEL, TEL AVIV CITY SYSTEM)

HTTPS://WWW.TEL-O-FUN.CO.IL/EN

ECO-VOLIS (ALBANIA, TIRANA CITY SYSTEM)

HTTP://WWW.ECO-BIKE.ORG

TOBIKE (ITALY, TURIN CITY SYSTEM)

HTTP://WWW.TOBIKE.IT/

BAYBIKE (JAPAN, YOKOHAMA CITY SYSTEM)

HTTP://DOCOMO-CYCLE.JP/YOKOHAMA/

24. List Of References

- Alta Planning + Design, 2012. *Cincinatti Bike Sharing Feasibility Study*. [pdf] Cincinatti. Available at: http://www.cincinnati-oh.gov/bikes/linkservid/241025ED-EFF8-8292-8C6AC74C67C3F7FA/showMeta/0/ [Accessed 21 October 2013]
- B-cycle, 2013. *How It Works*. [online] Available at: https://www.bcycle.com/howitworks.aspx [Accessed 3 November 2013]
- Bautista, B. 2014, Smart ElectricalWheel for Electrical Bikes , application no. 2014039745, 6 February, last viewed 30 April 2014,
- Brewster, J. 2003, Latch device for securing cargo containers, application no. 2003034654, 20 February, last viewed 14 February 2014,
- Cherry, C., Worley, S., Jordan, D., 2011. *Electric Bike Sharing System Requirements and Operational Concepts.* [pdf] Available at: http://cycleushare.utk.edu/cycleushare/Presentations_and_Press_files/final.pdf [Accessed 6 November 2013]
- City of Antwerp., 2013. *Uitgangspunt Demografie* [pdf] Antwerp: Dienst Bevolking, Available at: http://www.antwerpen.be/docs/Stad/Bedrijven/Cultuur_sport_recreatie/CS_Sport/4%20 uitgangspunt%20demografie.pdf [Accessed 25 November 2013]
- Colville, M., 2010. *Bike Culture by Design*. [video online] Available at:http://www.youtube.com/watch?v=070-TASvIxY [Accessed 1 November 2013].
- Colville, M., 2013a. Copenhagenize, *The Bike Share Bicycle Copenhagen ALMOST Had*. [online] Available at: http://www.copenhagenize.com/2013/05/the-bike-share-bicycle-copenhagen.html [Accessed 20 October 2013]
- Colville, M., 2013b. *On urban cycling. Mikael Colville-Andersen*. [video online] Available at:http://www.youtube.com/watch?v=1NLZo12HaeY [Accessed 31 October 2013].
- Vyncke, T., tobias.vyncke@gapa.antwerpen.be, 2013. Leenfietsen in Antwerpen, de uitgangspunten. [pdf included with email] Message to F. Breës (fabian.brees@gmail.com). Sent Friday 22 November 2013, 13:22

- Cyclopolis, 2011. *Brief History of Bike-Sharing*. [online] Available at: http://www.cyclopolis.gr/index. php/en/brhistory [Accessed 12 October 2013]
- Cykel DK, 2013. *How to.* [online] Available at: http://byogpendlercyklen.dk/en/how-to/ [Accessed 23 November 2013]
- DeMaio, P., 2009. Bike-sharing: History, Impacts, Models of Provision, and Future. [pdf] Available at: http://nctr.usf.edu/jpt/pdf/JPT12-4DeMaio.pdf [Accessed 28 October 2013] *Journal of Public Transportation, Vol. 12, No. 4*.
- DeMaio, P. 2013. *Sneak Peak at Copenhagen's Cykel DK*. [online] Available at: http://bike-sharing.blogspot.be/2013/08/sneak-peak-at-copenhagens-cykel-dk.html [Accessed 18 November 2013]
- Dhameja, S., 2002. Electric Vehicle Battery Systems. Woburn: Butterworth-Heinemann.
- EPOMM, 2012. *EPOMM Newsletter October 2012*. [online] Available at: http://www.epomm.eu/newsletter/electronic/1012_EPOMM_enews.php [Accessed 24 November 2013]
- Examiner.com, 2013. *Elf bike: Car-bicycle hybrid for sale*. [online] Available at: http://www.examiner.com/article/elf-bike-car-bicycle-hybrid-for-sale [Accessed 17 November 2013]
- Mersky, *R. 2014, Mobile Device Holder*, application no. 20140091192, 3 April, last viewed 24 April 2014, https://www.google.com/patents/US20140091192?dq=mobile+device+holder&hl=nl&sa=X&ei=zaRjU9-eLMPkOrGCgeAG&ved=0CDcQ6AEwADgK>
- Morchin, W. and Oman, H., 2006. *Electric Bicycles A Guide to Design and Use*. Hoboken, New Jersey: John Wiley & Sons, Inc.
- New York City Department of City Planning, 2009. Bike-Share Opportunities in NewYork City. [pdf] New York: Department of City Planning.
- Phys.Org, 2013. *Not a car or bicycle, but a blend: an ELF vehicle*. [online] Available at: http://phys.org/news/2013-07-car-bicycle-blendan-elf-vehicle.html [Accessed 17 November 2013]
- Rondeaux, D., dimitri.rondeaux@velo-antwerpen.be, 2013. productontwikkeling. [email] Message to F. Breës (fabian.brees@gmail.com). Sent Wednesday 9 October 2013, 09:10

- Satincesena Bicycles, 2010. *Bicycle Frame Making with Aluminum Alloy* [online] Available at: http://www.satincesena.net [Accessed 5 May 2014]
- Schiller, B., 2013. Co.Exist, What real time data tells us about the future of bike sharing around the world. [online] Available at: http://www.fastcoexist.com/3016869/what-real-time-data-tells-us-about-the-future-of-bike-sharing-around-the-world [Accessed 16 November 2013]
- Schmidt, A., 2013. *The guide to cycling ergonomics*.[pdf] Ruhr: Wilhelm Humpert GmbH & Co. Available at: http://www.humpert.com/en_media/bikeparts/downloads/ergonomieberater/visuals/ergotecErgonomieberaterEnglish_2013.pdf [Accessed 25 November 2013]
- Stanners, P., 2013. The future of city bikes or a waste of money? *The Copenhagen Post*, [online] 31 August. Available at: http://cphpost.dk/local/future-city-bikes-or-waste-money [Accessed 20 October 2013]
- United Nations Department of Economic and Social Affairs, 2011. *Bicycle-sharing schemes: enhancing sustainable mobility in urban areas*. [pdf] New York: United Nations Department of Economic and Social Affairs. Available at: http://www.un.org/esa/dsd/resources/res_pdfs/csd-19/Background-Paper8-P. Midgley-Bicycle.pdf [Accessed 5 October 2013]
- Vivanco, L., 2013. Reconsidering the Bicycle: An Anthropological Perspective on a New (Old) Thing. New york: Routledge
- Wheathly, *A. 2009, Frictional holding pad*, application no. 20090004420, 1 January, last viewed 24 April 2014, https://www.google.com/patents/US20090004420#legal-events/
- Wheathly, *A. 2013, Frictional holding pad with inclined grip*, application no. 20130292440, 10 January, last viewed 24 April 2014, hl=nl&sa=X&ei=_ZFjU9byN8eaO6nigdAI&ved=0CFwQ6AEwBA#backward-citations>
- Whitten, J. 2013, Case and mount system for handheld electronic device, application no. 20130181584, 18 July, last viewed 24 April 2014, https://www.google.com/patents/US2013 0181584?dq=case+and+mount+system+for+electronic+device&hl=nl&sa=X&ei=Y6VjU8v_MIGSO4ONgIAL&ved=0CEQQ6AEwAQ>
- Wireless Planet, 2011. *Wireless Power* [online] Available at: http://www.wirelesspowerplanet.com/wireless-power/ [Accessed 21 October 2013]
- N/A. 2013, Simple lifting bicycle saddle, application no. 202703759, 30 January, last viewed 9 April 2014, https://www.google.com/patents/CN202703759U?cl=en&dq=simple+saddle+lifting&hl=nl&sa=X&ei=daZjU76FJsHVPL2SgIAD&ved=0CDgQ6AEwAA>